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ROAD SAFETY - EXPERIMENTAL SAFETY VEHICLE. (REPORT ON THE THIRD INTERNATIONAL TECHNICAL CONFERENCE)

NATO Committee on the Challenges of
Modern Society

Prepared for:

National Highway Traffic Safety
Administration

June 1972

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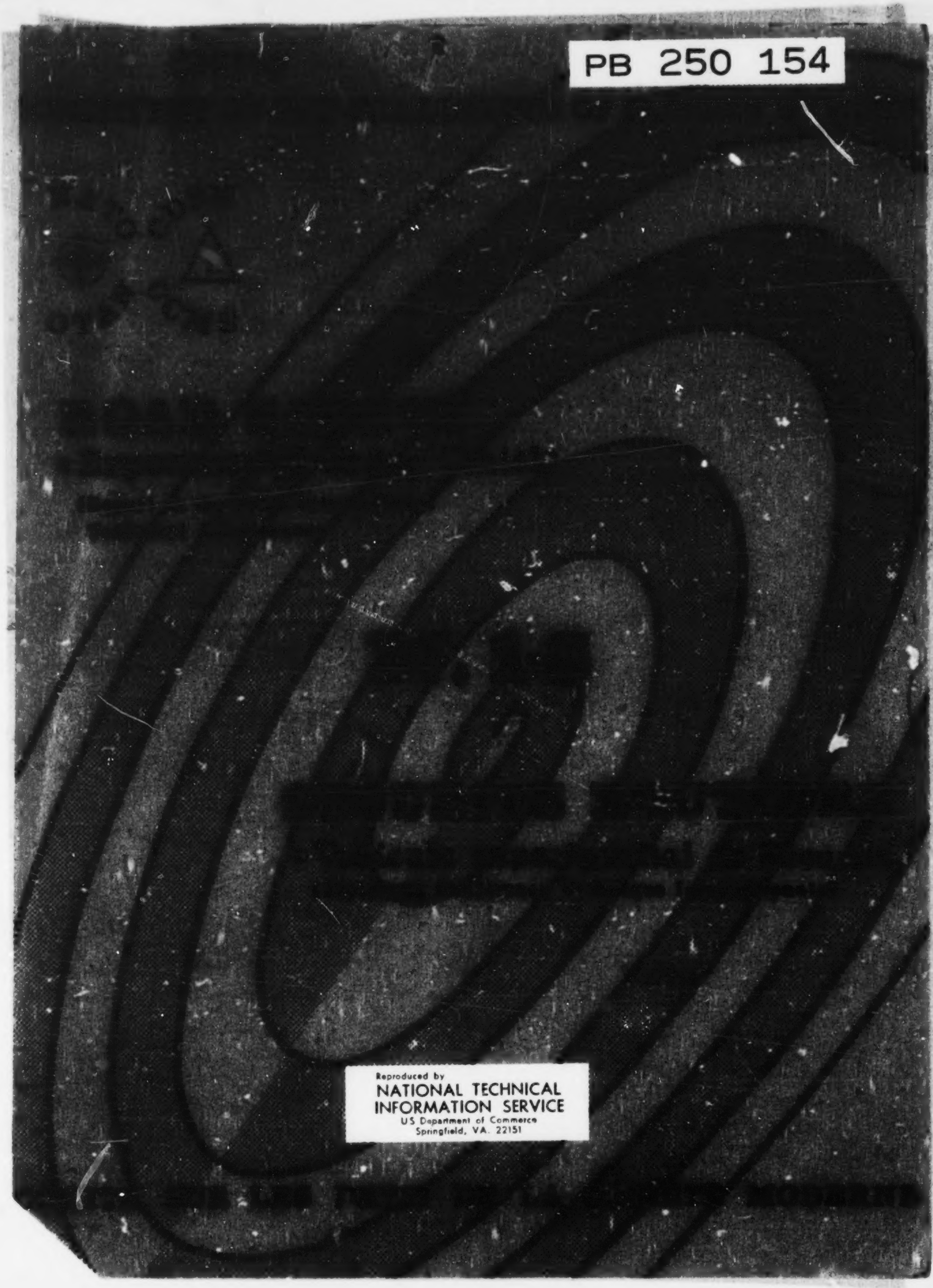

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REPORT ON THE THIRD INTERNATIONAL TECHNICAL CONFERENCE ON EXPERIMENTAL SAFETY VEHICLES

NATO CDSM
OTAN CCMS

Sponsor: U.S. Department of Transportation

Host: U.S. Department of Transportation

Held at: The Washington Hilton Hotel
Washington, D.C.
May 30 - June 2, 1972

U.S. DEPARTMENT OF TRANSPORTATION

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FOREWORD

THIRD INTERNATIONAL TECHNICAL CONFERENCE ON EXPERIMENTAL SAFETY VEHICLES

This report of the proceedings of the Third International Technical Conference on Experimental Safety Vehicles was prepared by the Office of Experimental Safety Vehicle Programs, National Highway Traffic Safety Administration, United States Department of Transportation.

The report includes the conference opening remarks, status reports by governmental representatives, the formal technical presentations by the automotive industries participating, a discussion period on rulemaking and experimental safety vehicles, and summations and concluding remarks by the United States.

For clarity and because of some translation difficulties, a certain amount of editing was necessary. Apologies are therefore offered where the transcription is not exact.

AGENDA

THIRD INTERNATIONAL TECHNICAL CONFERENCE ON EXPERIMENTAL SAFETY VEHICLES

Tuesday, May 30	0830-0930	Registration
	0930-1000	Conference Opening
	1000-1200	Status Reports by participating Governments: United States Germany Japan Great Britain Italy France Sweden Belgium
	1200-1330	Lunch
	1330-1530	French ESV Presentation
	1530-1730	British ESV Presentation
	1730-1800	Discussion
Wednesday, May 31	0900-1000	Swedish ESV Presentation
	1000-1200	Italian ESV Presentation
	1200-1330	Lunch
	1330-1630	Germany ESV Presentation
	1630-1730	Discussion
Thursday, June 1	0900-1200	Japanese ESV Presentation
	1200-1330	Lunch
	1330-1530	American ESV Presentation (GM, Ford, U.S. Government)
	1530-1700	Discussion – Rulemaking and the ESV
	1700-1730	Summation and Conclusion
	1830	International Transportation Congress Banquet, Sheraton-Park Hotel (special reservations required)
Friday, June 2	ALL DAY	Visit Transpo '72 Exhibits Dulles International Airport

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Mr. Robert L. Carter, *Associate Administrator for Motor Vehicle Programs, National Highway Traffic Safety Administration, United States Department of Transportation*
Mr. Albert J. Slechter, *Assistant Director, Office of Experimental Safety Vehicle Programs, National Highway Traffic Safety Administration, United States Department of Transportation*
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SPECIAL SECTION THE CONSOLIDATED INTERNATIONAL ESV EXHIBIT AT TRANSPO '72, DULLES INTERNATIONAL AIRPORT, WASHINGTON, D.C., MAY 27 THROUGH JUNE 4, 1972.

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Mr. John A. Edwards, *Associate Administrator for Research and Development, Research Institute, National Highway Traffic Safety Administration, United States Department of Transportation and Chairman of the Third International Technical Conference on Experimental Safety Vehicles*

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CONFERENCE OPENING

SECTION 1 PART 1

INTRODUCTION BY THE CHAIRMAN OF THE THIRD INTERNATIONAL TECHNICAL CONFERENCE ON EXPERIMENTAL SAFETY VEHICLES

CHAIRMAN JOHN A. EDWARDS, *Associate Administrator for Research and Development*

Research Institute, National Highway Traffic Safety Administration
United States Department of Transportation

Good morning ladies and gentlemen, it is again my pleasure to serve as your chairman for the Third International Technical Conference on Experimental Safety Vehicles. To open our conference, it is my honor and privilege to introduce the Honorable John A. Volpe, Secretary, the United States Department of Transportation and your host for this Third ESV Conference. Secretary Volpe . . .

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INTRODUCTORY REMARKS

SECTION 1 PART 2

THE HONORABLE JOHN A. VOLPE, *Secretary*

United States Department of Transportation

Today I am extremely proud to open the Third International Technical Conference on Experimental Safety Vehicles.

It has been only two short years since the world's auto-producing countries began energetically to address themselves to the problem of developing ESV's. But as you will see during this conference, the progress has been truly outstanding.

Two years ago — April 1970 to be exact — the United States first proposed that a cooperative research and development program be undertaken to improve significantly the safety performance of automobiles. We had been studying for some time needed changes in the safety design requirements for the standard sized American car. We proposed to our overseas friends that they undertake the development of ESV's in the lightweight class, in which they had so much experience.

The completion of international agreements is often a difficult and time-consuming task, and I am particularly proud of the record speed with which we were able to conclude bi-lateral ESV agreements. The first agreement was signed in November 1970 by my very good friend Minister Georg Leber in Bonn and myself.

This was followed quickly by an agreement with Japan, which has been an early enthusiastic supporter of the ESV concept. The United Kingdom, Italy, and France joined the program a few months later. With the signing of an agreement with Sweden this year, all major auto-producing countries in the world are now participating.

Even while inter-governmental discussions were going on, the world's auto manufacturers were busy on vehicle development. The First International Conference, graciously hosted by the French in Paris in January 1971, disclosed the extensive theoretical work being done in energy management and structural design. The Second International Conference, which, thanks to our German hosts, we shall long remember, took place in Stuttgart in October 1971 and revealed the intensive crash test program of many manufacturers. In addition the American ESV manufacturers, Fairchild Industries, American Machine and Foundry, General Motors, and Ford presented full descriptions of their prototypes.

At this Third Conference, you will see much has been done since last fall — especially as you visit the ESV exhibit dome at Transpo '72. There, a number of manufacturers are presenting, for the first time, complete ESV prototypes. And of course, at this meeting, the exchange of technical information on the ESV program between the participating countries will continue.

The basic idea underlying the ESV program is simply this: We all recognize that much more can be done to improve the safety performance of motor vehicles by designing a car *from the ground up* with safety as its primary goal. The consequences of adoption of this simple concept have already been truly outstanding. Auto design engineers, freed for the first time from the constraint of styling and pricing factors, have thrown themselves into the ESV task with unparalleled enthusiasm. Top company management have unhesitatingly committed millions of dollars to the ESV program. They have allotted tens of thousands of scarce engineering man-hours to the project and have constructed and equipped extensive new test facilities. Governments have come to the support of these efforts by undertaking new research at government centers, as well as underwriting a great deal of private research.

The result of all of this work is now emerging and we begin to see the car of the very near future. Passengers will ride in cars that will fully protect them in head-on crashes of 40 or even 50 miles per hour, in rollover accidents at speeds up to 60 or 70 miles per hour, and in severe side impact collisions. Better braking, better lighting, greater visibility, and better all-around handling and stability will enable

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even the average driver to avoid accidents. And this will be achieved *not* by building a "Sherman tank" as some early critics of the program forecast, but by preserving, even enhancing, the styling features of current production models.

The program has not yet reached the point where reasonably accurate estimates can be made of the cost of translating new safety solutions to production vehicles. I am convinced, however, that the safe car of the near future can be marketed at little more than current prices. I know there are many here who might be skeptical of that statement, and I want them to know that I appreciate the effort that they will have to make to achieve the necessary cost reduction. Nonetheless, the very process of translating R-and-D work into mass production operates in a competitive market to reduce costs. Let me cite one example: at the time the Department of Transportation first proposed its standard for a 5 mile per hour bumper, industry was concerned with the increased weight requirement and projections of substantial increases in price the consumer would have to pay. However, within a short time, a relatively small European manufacturer produced a bumper constructed with new materials that was not only lighter in weight than conventional steel bumpers, but also cost even less than the old design. And the bumper fully meets the 5 mile per hour crash speed requirements of the standard!

These last considerations bring us to another major objective of the ESV program — to incorporate the safety features demonstrated by the prototype ESV's into requirements for mass production vehicles. I am sure you will all be interested in the session that has been scheduled at this conference to discuss the relationship of the ESV program to the safety standards we are working on for the near future. However important the discussions that take place during this session, they can only be a beginning. All of the governments represented here today must begin to study the ways and means by which the work done on ESV's can be translated into production model requirements.

We in the Department of Transportation are working on this now, and are prepared to exchange our ideas as to how this can best be accomplished with all of our ESV partners. At the appropriate time, I hope another international meeting can be held on this all-important topic to discuss how we can assure the maximum uniformity, on the international level of vehicle safety standards.

I am sure that you will have recognized from the brief remarks I have made this morning the dual nature of the ESV program — that is, the competitive and cooperative approaches. As you will see when you visit the ESV exhibit at Transpo '72, individual companies have taken different approaches and produced very different prototypes. This intense national competition has resulted in rapid progress and the attainment of a higher level of safety objectives. Once the initial designs were fixed an exchange of technical information enabled the countries to learn from each other.

But the real competition is not between companies or between countries; it is with the specter of death and injury that haunts our highways. In whatever way we can, we must insure through competitive invention or through international cooperation that the lives of our citizens must and *will* be protected against the hazards of the road.

MR. RUSSEL TRAIN, *Chairman*

Council on Environmental Quality and United States Representative to CCMS, NATO

International cooperation in Experimental Safety Vehicle developments is one of the principal projects in the road safety project study which the United States is leading for the Committee on the Challenges of Modern Society of NATO. As the United States representative to the CCMS, I am delighted to be here at this impressive demonstration of how major automotive producing nations of the world can work together on vehicle safety problems of mutual concern.

The CCMS effort stems directly from a proposal that President Nixon made to NATO in April 1969, less than four months after taking office. The President called upon NATO to broaden its efforts beyond its primary mission of military defense and related political cooperation to social problems of mutual concern with the quality of life for 20th Century man. NATO responded and created the CCMS.

From the start, President Nixon has had a strong personal interest in CCMS. The ESV program has been one of the outstanding achievements to date and one which has very much impressed the President. Today, I bring you his personal greetings and best wishes for a productive meeting and continued success of the project.

One cannot talk about the international ESV program without associating it with Secretary of Transportation John A. Volpe. Secretary Volpe has led in expanding the U.S. ESV program into an international effort, negotiating separate bilateral ESV development agreements with six of the major automotive producing nations of the world, the Federal Republic of Germany, France, Italy, the United Kingdom, Japan and Sweden.

In passing, I would like to mention that a balanced road safety program involves, of course, much more than safe vehicles. The overall CCMS Road Safety Study thus includes the following subjects:

- Accident Investigation led by the Netherlands
- Alcohol and Highway Safety led by Canada
- Motor Vehicle Inspection led by Germany
- Emergency Medical Service led by Italy
- Pedestrian Safety led by Belgium
- Road Hazards led by France

Together, these comprise a balanced approach to the overall problem. We are most confident that useful solutions and new actions will result which will benefit everyone.

Finally, CCMS is directed to a number of other problems focusing on the environment and quality of life. Time doesn't permit me to go into this in detail, but CCMS projects exist in such diverse areas as air pollution, ocean pollution, regional planning and the environment, work satisfaction in a technological era, advanced health care services, inland water pollution and advanced waste water treatment. CCMS has been especially innovative in developing new methods of international cooperation utilizing the pilot project approach.

This is a time when we have exceptional opportunities for the nations of this world to join together to help solve the problems they share in common. Never before have the public and their governments been more aware of the possibly detrimental effects of the onward rush of new technology and unplanned growth. The ESV program is a truly pioneer attempt to redress some of the most dangerous aspects of the automobile revolution. It is my hope that it will act as a model for new international cooperative initiatives which aim towards making our daily lives less dangerous and more healthy.

Finally, it is clear that these and other challenges to the quality of life transcend national boundaries. It is only fitting that they be attacked in a spirit of cooperation and mutual understanding. This meeting exemplifies this spirit as do the continuing traffic death tolls on the highways of the world highlight the need for action.

DR. GUNNAR RANDERS, *Assistant Secretary General and Chairman*

The Committee on Challenges of Modern Society (CCMS), NATO

When we consider the challenges which confront modern society, surely one of the foremost is how to provide safe, comfortable, and rapid transportation. Nowhere is the safety of the citizen threatened incessantly as on our streets and highways. That is precisely why NATO's Committee on the Challenges of Modern Society chose the Road Safety Project among the first of its pilot projects.

Within the Road Safety Project, development of Experimental Safety Vehicles has been a primary objective. Indeed, there has been widespread international interest in the development of ESV's, both in NATO and non-NATO countries. This important conference is indicative of the extent of international involvement in ESV development. A number of ESV prototypes have already been subjected to field testing, and this will continue as others are developed in both the 4,000- and 2,000-pound categories. We at NATO share the view that, as a result, possibilities are increased for significant improvements in the design and manufacture of motor vehicles which will make them safer — which will indeed contribute to saving lives on our roadways.

Through its Road Safety Project — as well as its other pilot projects — NATO CCMS has demonstrated its concern with the human condition. NATO's responsibility is to assure the security and well-being of the people who live in NATO countries. Their security depends upon the strength and cohesion of the Alliance; their well-being depends upon those conditions of modern life under which they live, the quality of their lives.

Their lives are affected by the changing ecological balance. It is the paradox of our times that the very progress achieved by man in the technological and social fields originally intended to improve his way of living, now poses challenges to present and future generations. Recognizing this, NATO has long concerned itself with the scientific and technological aspects of modern society and, in addition, somewhat over two years ago established the CCMS to deal directly with modern-day problems.

The CCMS has already made considerable advances in helping countries to cope more effectively with problems of ocean oil pollution, disaster assistance, and air pollution. CCMS pilot studies in other priority areas — notably road safety — are underway. The results of this and other pilot studies will be made freely available to all. The primary objective is action, early and effective action at the national and international levels to affect the undesirable aspects of technological development.

As it has in the past, NATO will continue to manifest its concern with the quality of life within the Alliance. Building on its past achievements, the CCMS will continue to contribute to those national and international efforts designed to meet the challenges of modern society.

MR. DOUGLAS W. TOMS, *Administrator*

National Highway Traffic Safety Administration
United States Department of Transportation

On behalf of all of us who labor in the government vineyards, I welcome you to this Third International Technical Conference.

I am very pleased at the number of people that I recognize this morning. It is true that many people around the world in auto-producing nations have gotten to know one another very well, as a result of the ESV Program, and share many of the mutual problems that we are facing in trying to build safer cars and create safer roadways.

I probably should also add make safer drivers, too.

Naturally, we are very pleased to have you in our Capital City. We in the National Highway Traffic Safety Administration have looked forward to this day when we could be the host to an ESV conference. I am sure that we cannot top our esteemed colleagues in Germany. The Stuttgart conference has got to be, at least to date, an all-time high in conference arrangements. It was a marvelous job, and we again wish to thank our colleagues in Germany for their excellent support.

We can't offer you castles and the impressive banquets that we have experienced in the past but, nevertheless, I can assure you that, on behalf of John and Al and Pete and all the guys in the National Highway Traffic Safety Administration, we are going to do our level best to make you comfortable here and try to insure that you will not only have a good time in Washington, D.C., but that it will be a fruitful conference.

I hope by the end of the conference that we will have an opportunity to announce where the next ESV conference will be. And I think, as many of you know, we are shooting for nine-month intervals.

I can't help but be amused that one of our colleagues had a baby during the last ESV conference and was told, "Well, we have got things planned so you can have one for every conference."

We are hopeful that the next conference will be in Japan, and we don't know exactly in what month or in exactly what city, but we are looking forward to that possibility. It looks now that perhaps after Japan our colleagues from the United Kingdom will be in a position to host the Fifth ESV Conference.

I am pleased with our facilities here, John. It is a lovely room. I think you have things laid out very well. If any of the delegations can think of something that we can do to our facilities to make the conference better for you or more meaningful for you, please see Pete or John and we will do whatever we can to make adjustments.

Further, don't hesitate to call on us for any favor that we can perform for you. If you do need help in preparing a manuscript or require assistance in any way, please let us know.

The Secretary made some comments about Transpo. As you can well guess, many of us have been out there every day for the past few days. It is a great show. I hope that you will plan to stay through Friday and that you will go out to Transpo. I think the ESV exhibit is an excellent display of the fruits of your labor.

I have been told that the ESV exhibit at Transpo has been the most heavily attended of all the exhibits out there. And I want to encourage all of you to go out and take a look.

Further, for all of those of us who work in the field of transportation, never have I seen such an assemblage of automobiles, trains, hover craft, aircraft cars and all manner of things that relate to the nature of our work.

So I wish you a good stay while you are here. I hope that you will learn a lot, like I am sure that I will. And I hope too, that you will have a nice time.

SECTION 1 PART 3

STATUS REPORTS BY GOVERNMENTAL REPRESENTATIVES ON THEIR EXPERIMENTAL SAFETY VEHICLE PROGRAMS

UNITED STATES

MR. JOHN A. EDWARDS, *Associate Administrator for Research and Development*

Research Institute, National Highway Traffic Safety Administration
United States Department of Transportation

INTRODUCTION

Good morning, Ladies and Gentlemen.

It is my pleasure to present the status of the United States' Experimental Safety Vehicle program. Much has been accomplished since our last meeting in Stuttgart, Germany, in October. As you will recall in Stuttgart, the United States technical presentation included a briefing by AMF Incorporated and Fairchild Industries on the final designs for their prototype ESV's. Also, at that time, the General Motors Corporation reviewed their preliminary design solutions and discussed the results of initial development tests, and the Ford Motor Company presented their initial conceptual design approach to satisfy the ESV performance specifications.

In December of 1971, the United States government accepted the first completed AMF and Fairchild prototype ESV's. The second car from each contractor was received in January 1972. These prototype vehicles were immediately entered into the competitive test program. The General Motors' ESV's are scheduled for delivery to the government in July 1972, some four months ahead of the contract delivery date of October 1972. The Ford Motor Company ESV will be delivered on schedule in late December 1972. Here again, upon delivery to the government, these vehicles will be immediately entered into the test program. I would now like to spend a few minutes to review the ESV test program.

The AMF prototype car was crash tested into the barrier at 49.70 mph on March 31, 1972, and the Fairchild ESV went into the barrier at 48.95 mph on April 18, 1972. Many of you here today had the opportunity to personally witness this latter test. However, prior to these rather spectacular crash tests a great deal of preparatory work had to be accomplished.

Dynamic Science spent the period from July 1971 to January 1972, upgrading their test facilities and conducting the necessary baseline tests in preparation for prototype testing. Testing of the follow-on vehicles and the General Motors and Ford prototypes will carry on into mid-1974. However, during the testing period, we will continuously assess the test results as they become available to determine what potential rulemaking recommendations are appropriate.

We are very interested in having each country participate in this test program by sending one or more vehicles to the United States for testing, and will continue to pursue this interest as the program progresses.

FUTURE PLANS

The United States ESV Programs Office staff has been extremely busy evaluating the results of tests performed on the prototype ESV's in preparation for the award of the follow-on contract. Based on the results of these competitive "drive-off" tests and evaluations now in progress, a follow-on contract for design optimization and fabrication of additional cars will be awarded to that contractor, AMF or Fairchild Industries, whose prototype ESV demonstrates the best overall safety performance. The major thrust of the ESV follow-on program will be towards the optimization of one of these designs based on our experience to date. In addition, the significant amount of new knowledge and technical information becoming available, as a result of development work accomplished by the participants in this international program, will be directly applied.

In this regard, our schedule for the optimization program is as follows:

Specification Analysis	Summer 1972
Design Optimization & Development Testing Completion	Spring 1973
Final Design Completion	Summer 1973
Vehicle Deliveries	Fall & Winter 1973
Vehicle Testing Completion	Summer 1974

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I take this opportunity to invite all here today to participate in the first step of the follow-on ESV program – the analysis of our current ESV performance specification.

Each participating country has had an opportunity to assess the impact of the first U.S. specifications on ESV designs. Some of you are, I am sure, ready to discuss specification alternatives, based on performance test information, that will move us a step closer to improving practicability of vehicle designs. We want to obtain comments from each participant during the summer months in order to arrive at a specification in September for our optimized design. You will hear more of this in the United States' technical presentation on Thursday.

CONCLUSION

This concludes my status report on the United States ESV program. During the U.S. technical presentation on Thursday, both the General Motors Corporation and the Ford Motor Company will review their ESV programs. In addition, the U.S. ESV Programs Office will present the results of our test work to date, and introduce additional details of our follow-on optimization program.

Thank you very much.

GERMANY

MR. HELMUT WAGNER, ***Ministerial Director***

Federal Ministry of Transport

Ladies and gentlemen, I am indeed very happy to be able to tell you in a few brief words, words that certainly come from our heart, what has been done in the time between the last conference and this conference. What has been done in our country.

This was a very brief period. There were only a few months available to us, and therefore the status that we outlined to you in our Stuttgart report has not really changed. Nevertheless, I would like to mention five points which are pertinent now, and that indicate that progress really has been achieved.

The first is the fact that Mercedez-Benz has created a new model of an ESV vehicle which you will see here in our exhibit at Dulles. This firm has been occupied with the optimum solution of the restraint structures and with the esthetics of structures, how one can form in a pleasing way the front and rear of the car. For what is useful need not always be ugly.

The second important event I want to touch upon is the fact that the Volkswagen firm has followed up certain design ideas with a model that is now also being shown at the exhibit at Dulles. You will get further details later, but it seems to me of importance that this model is based upon a very thorough consideration of cost effectiveness analysis. Volkswagen really thought about the three factors that impact here – the man, the environment and technology. They also dealt with the problem that arises between large and small cars, particularly if one has already seen the ESV prototypes.

The third manufacturer, Opel, has made additional progress since their report in Stuttgart on absorption of energy and forces in collisions, the inner safety. Here again we tried to orient ourselves to the empirical event, the actual impact, the actual experience in collisions, so that what is being done can be directed at the true sources of danger.

In this connection, I want to note the fourth point. We have received very useful help from our insurance industry. Very large numbers of collision events have been analyzed and we tried to draw conclusions from these for the so-called "internal safety." The technical reports that will follow give you further details and I may therefore be excused if I don't discuss these details now.

The fifth point that we should consider is the conclusions and the consequences which are about to be drawn from these elaborations. We now have five ESV prototypes which are being presented here. What then, of the experience that has been gained so far in the various countries? How are we to cooperate? How are we to understand each other and how are we to unify the regulations? Are we to create international regulations? Should we distribute the various research and development projects? Are we to deal with statistical problems in cooperation? All of these problems must be dealt with in the very near future, and my government intends to cooperate fully with the United States government to establish a memorandum of understanding so that the information may be fully exchanged, so that the basis may be formed for full cooperation in this field.

Finally, I want to thank all those who participated in the organization of this International Conference. These conferences make it possible for us not only to talk to each other in this very room but also on a personal level. This will certainly help us to gain new knowledge and experiences and to bring us new and fruitful progress and innovations in the coming year.

I wish to thank you again and I wish you a very interesting and fruitful conference and discussion in this forum of the problems that are of utmost interest to all of us.

Thank you very much.

JAPAN

MR. YOSHIMOSU IZUKA, *Director*

Engineering Division, Road Transport Bureau, Ministry of Transport

The Japanese ESV Program was first formulated in May 1971 by three automobile manufacturers, Toyota Motor Company, Nissan Motor Company and Honda Motor Company.

Progress in this program has been made since then in accordance with the general original plan, and final ESV's are to be completed toward the end of 1973 by Toyota and Nissan Motor Companies, while the Honda's will be completed by the end of 1974. Strenuous efforts are being made by the persons concerned to realize their objective.

The results of experiments conducted up to the present by these participating manufacturers and their technical problems will be reported in detail by each of the manufacturers at the meeting scheduled for the day after tomorrow. Therefore, today I would like to make a brief report on the progress situation of the Japanese ESV program.

Toyota Motor and Nissan Motor each have built full scale models by embodying all the results obtained from various tests on the remodelled cars of conventional type and on other models set up for specific tests on functional parts. They are on display at Transpo '72.

It is scheduled to build this kind of prototypes by the summer or fall of this year and commence various tests. Through the tests, it is intended to resolve technical problems and final ESV's will be completed, as said above, by the end of 1973 and delivered to the government.

On the other hand, Honda Motor is working on a very light car or 1500-pound class in its ESV program. Since the test data on this class of vehicles are few as compared with other types of vehicles, crash tests are being conducted by use of the most light vehicles currently under mass production. Thus, the basic problems are being studied related to the light vehicles of this class.

Through the results of these tests conducted by the three manufacturers, problematic points in the small-sized cars are being made clear. However, many kinds of problems to be solved still remain, such as the crash speed, the problem of keeping the weight within the target value and the like.

The performance tests of final ESV's will be conducted at the Japanese Automobile Research Institute. The government aids have been given to this Institute to build facilities required for the tests; they include a vehicle-dynamics proving ground, tire testing laboratory, engine laboratory for variable ambient conditions, exhaust emission testing facilities and others. Their construction is now under way as originally planned. In doing the performance tests, a big problem will be the establishment of evaluation procedures of ESV's.

In April this year, open crash tests of the American ESV's took place for the people concerned in the field, which is really beneficial for all of us who undertake the tests in the future. Therefore, I hope similar tests for the future will be open to us as far as permissible. And further, it is most desirable to have an exchange of technical information on ESV programs among the participating countries in a more positive manner.

I believe that the ESV program is a marvelous project in which the best of all the safety technology of modern times will be accumulated. Therefore, we anticipate the developed technology from the program will form the guideline for the safety of the future.

In Japan, a long-term program plan of motor vehicles safety standards is being discussed at the Transport Technology Advisory Council, and a final plan is scheduled to be presented in the very near future. It will be proposed in the plan to place the importance of safety measures for pedestrians on an even level with that for occupants' safety.

Finally, we would like to express our sincere respect and gratitude to the United States Government and the members concerned with the Conference for their efforts to hold this Third International ESV Conference.

UNITED KINGDOM

MR. ELDON GRIFFITHS, M.P., *Parliamentary Under-Secretary*

British Department of the Environment

The United States Government, when it proposed that the development of Experimental Safety Vehicles should be included in the Committee for the Challenge of Modern Society program, took an important initiative towards making driving safer. It was — and it is — an initiative most welcome to the United Kingdom and I should like this morning to offer my Government's thanks — and congratulations — to the United States, and to Secretary John Volpe in particular, for hosting this valuable and, I hope, constructive Conference in conjunction with their imaginative Transpo 1972.

The British Minister for Transport Industries who would himself have liked to be here has asked me to convey his personal best wishes to the Conference. He has taken a close interest in the United Kingdom's preparations and I know he was disappointed that last minute pressure of business prevented him from being here today.

Mr. Peyton and I are colleagues in the newly-created Department of the Environment. This reflects our conclusion, in Britain, that transport in all its aspects needs to be organized as an integral part of our management of the environment. How, and how well or how badly, we arrange to travel to work and to play or to carry our freight and commerce, are questions we believe that no longer can be separated from the business of land-use planning, regional and urban policy, and the fight to control pollution. Transport, in short, is crucial to the quality of our environment — and that is why, before coming to the United Kingdom safety vehicles, I venture to say a word about our overall approach to what we all — by our presence here in Washington — acknowledge to be a challenge to modern society. The motor vehicle was recently described as the "beloved horror." I am not sure that is quite fair; yet many people in my country assuredly are coming to regard it as part mistress and part monster. Part mistress, because few possessions are the object of more fond male attention — or indeed, more lavish spending than is the motor vehicle; part monster, because the same motor vehicle kills and maims and destroys, can foul the air and deafen: at the same time, it steals an increasingly important area of our city center real estate which nowadays tends to be covered with steel and glass boxes, most of them standing idle!

Having said this, let me go on to affirm that I am, nevertheless, an unrepentant fan of the motorcar. It has undoubtedly liberated and widened the horizons of hundreds of millions of people in every continent. It relieves far more suffering than it causes, and taking one thing with another, it has the capacity to improve (and to go on improving) the quality of most people's lives.

But I must make one provision. If the motor vehicle is to serve man — and not man the motor vehicle — we need to civilize it. To make it cleaner and quieter. To make sure it knows its place. Above all, to make it safer. People matter more than motorcars — although motorcars can — and do — enrich people's lives.

In Britain, our approach to civilizing the motor vehicle is a partnership between government and industry. We do not regard our manufacturers as villains to be pilloried but as willing, indeed enthusiastic, participants in a joint campaign.

This campaign is now international. Clearly, as this Conference demonstrates, all our countries have a great deal to learn from one another. It is no longer a mainly one-way traffic from the United States to the rest of the world. Since the late 1940's and 50's when the U. S. produced seven out of ten of the world's cars there has been a shift in the balance of automotive power. Now, though the U. S. industry still leads the world — and owns or operates a good share of the automotive industries in many overseas countries, including the United Kingdom — now the league tables show that the Common Market countries, with whom I include my own country, equal or even exceed American car production. Then, too, there are our friends in Japan.

I mention this for one reason only — to underline the fact that in the 70's and 80's there is room — and need — for different approaches to the question of how to handle the multiplying motorcar. Our approach in Britain is, of course, reflecting our own circumstances, but increasingly it is coordinated with our European partners. Broadly speaking, we share their conditions, physical, social and climatic; so broadly speaking, as Europeans, we are pursuing a similar road.

CLEANER CARS

Thus in tackling vehicle pollution, we are about to make obligatory in the United Kingdom an ECE regulation which will reduce emissions of carbon monoxide by up to 30%, and of hydrocarbons by up to 10%. On our own account we have gone further and faster in two important respects: obligatory crank case breathers to cut hydrocarbon emissions by 25%; and, in the diesel field, the strictest standard in Europe on black smoke emissions on vehicles made after October 1, this year.

QUIETER VEHICLES

In the case of noise, we have since 1970 prescribed maximum levels, broadly in line with those in the rest of Europe for all new vehicles. But my Government would like to go further. We believe that a maximum level of 80 decibels can be achieved for private cars; 82 decibels for light vans; 86 decibels for trucks and buses up to 200 brake horsepower.

Our desire to reduce vehicle noise arises in large part out of a concern for safety. Driving a heavy truck places a heavy strain on the man in the cab, and if that cab is a resonating sound box within which the driver is deafened for hours on end, the strain can become intolerable. So our research program is aimed at producing a heavy truck with an 80 decibel limit — the same level as the private cars. We hope to introduce the prototype quiet truck by the end of 1975.

SAFETY

Coming now to safety vehicles, I am glad to be able to say that our safety record in Britain shows signs of improvement. The grisly statistics reveal that car user deaths per 100 million car miles are nearly 50% lower for Britain than they are in the United States, though our pedestrian record, I should add, is a good deal worse. The slaughter on our roads is nevertheless quite appalling. We intend to do all in our power to bring the carnage down.

BRITISH APPROACH

Our priority is for rapid actions and practical results. We have concentrated on three particular aspects — accident avoidance, occupant protection, and pedestrian safety. To prevent accidents happening, we are trying to ensure that our vehicles have better handling qualities, and that drivers have more information. To reduce the toll when accidents *do* happen, we are developing better ways of protecting the occupant, both by the vehicle's structure and by effective restraint and cushioning.

Given our domestic traffic conditions, where 40% of all road fatalities, sadly, are pedestrians, we also give high priority to designing vehicles so that injuries to pedestrians are minimized.

Overall, we have *not* concentrated on building a complete safety car — from scratch. The totally safe vehicle is almost certainly a myth; indeed, there is a danger that if we construct a car so buttressed that it looks like a cross between a tank and a padded cell that it may serve only to protect those *inside* at the expense of those *outside* — the passenger at the expense of the pedestrian.

Of course, if you actually enjoy a spot of claustrophobia, there may be something to be said for the padded cell approach — assuming you can afford it. But without any disrespect, Mr. Chairman, I am bound to observe that my reaction to some of the armoured car varieties I have seen in recent days is to conclude that there may be opening up a new export market for the British — namely armoured plating for pedestrians. We and our friends in Europe have a good deal of this available — hand-me-downs from the knights of old! More seriously, our approach has been directed to the development of systems and sub-systems — which can be readily incorporated, at a realistic cost, into existing production vehicles. Examples of this approach are on display at Transpo, and include:

(a) the two head-up display systems of speedometer reading and correct vehicle spacing. These avoid the necessity for the driver to remove his eyes from the horizontal plane for that vital 1.6 seconds it takes to check speed; they are now well advanced, simple to operate and can be installed at a very low cost.

(b) self-levelling and self-cleaning headlights. Obvious when you think about it, but an invaluable aid to the man who drives at night or in filthy weather — and we have our share of that!

(c) passive seat belts. Controversy surrounds the air bag as a means of driver/passenger restraint — but the seat belt is tried and tested. And the more simple one makes the device the less is the temptation to avoid using it.

(d) Perhaps I might also be forgiven a plug for one British company. The Dunlop Total Mobility Tire is, we think, the most significant step forward in its field since the same company invented the pneumatic tire. It has been burst at 100 miles an hour without any ill effect on vehicle stability.

As will be seen, we in Britain are not designing safety vehicles for the benefit of safety engineers. We are not going in for armour plating and padding regardless of the cost. The challenge before us is to make the motor vehicle safer in a manner which will be both speedy and effective, and also within the means of the ordinary family wanting to buy a car.

That indeed is what we mean by "civilizing" the motorcar. We want it cleaner, quieter and safer at a price which the public can afford, and I am sure that, at this Conference, industries and governments together will make useful progress towards a goal which is as urgent as it is desirable and humane.

UNITED KINGDOM

DR. H. TAYLOR, *Deputy Chief*

Transport Road Research Laboratory, Department of the Environment

Mr. Chairman,

I would like to express the appreciation of the combined British technical team of government and industry for this opportunity of meeting with our colleagues from other countries to discuss the international car safety program. It is particularly appropriate to be meeting here in Washington, D.C. in the pilot country for the road safety project and for our meeting to coincide with the other major transport activities of Transpo '72.

The main British contribution to the Third ESV Conference comprises an exhibition at Dulles International Airport and a technical presentation to be given here this afternoon. We have tried to link the two so that they present an up-to-date picture of the scope and progress of our work towards safer road vehicles. In view of the wide range of vehicles involved in Britain we have adopted a safety systems approach to the subjects of accident avoidance, occupant protection and pedestrian safety and in this way our projects retain flexibility and are near to the production line. We accept the necessity of demonstrating from time to time the successful integration of several safety features and the two vehicles exhibited by Britain at Dulles are intended to do just that. Between them they have over twenty special safety features covering the three major problem areas. The main responsibility for these cars has lain with the British Leyland Motor Corporation Limited and Joseph Lucas Limited respectively, ably supported by many other companies and by the Motor Industry Research Association. These organizations, together with the Society of Motor Manufacturers and Traders will be participating in this afternoon's technical session when many of the features exhibited at Dulles will be described. For ease of reference two booklets have been issued, one dealing in detail with the exhibits and with other British technical data, the other containing complete versions of the conference technical papers.

SAFETY SYSTEMS VEHICLES

The status of the U.K. program is well demonstrated by the two vehicles exhibited. Safety Systems Vehicle 1 is a version of the well-known MGB GT. The resulting vehicle is not a "dream" car but a fully integrated engineered product embodying developed safety features, most of which have been extensively tested or are currently undergoing evaluation.

Considering occupant protection, the basic car has already been successfully tested at 44 miles an hour in frontal impacts and has been further developed to withstand side impacts at over 20 miles an hour with negligible intrusion. The door is fitted with a strengthening rail and overlaps the main structure to which it is pegged for greater strength. The side structures are filled with energy absorbing foam. A low cost passive belt system is provided by a single diagonal belt combined with knee restraint and details of highly successful tests on this system will be described later today. The vehicle is also fitted with a fully passive air bag restraint system.

Accident avoidance has received considerable attention. There is a full power 4-wheel anti-lock braking system, together with a roll-free ride control suspension and total mobility run-flat tires. Speed and following distance are presented by a head-up display which eliminates the need for the driver to take his eyes off the road. Rear viewing is by periscope and there is a graded brake light display. An alcohol screening device for drunken drivers is also fitted.

Pedestrian safety has received attention by way of a first phase pro-pedestrian bumper designed to distribute the load in a pedestrian impact. As a result of investigating pedestrian accidents the bumper is set lower than in U. S. practice and has the further feature of being compatible with the side structure in side impacts.

The latest development in British anthropometric dummies is on show, tests having demonstrated consistent results when the dummy is subject to repeatable crash tests. A vital aspect of the British car safety program is the extent to which greater safety can be achieved without prohibitive increases in size, weight or cost. SSV1 is only some 3% over the weight of the standard car which is 2400 pounds, the associated cost increase however being estimated at approximately 30% on a mass production basis.

Safety System Vehicle 2 is basically a Triumph 2.5 PI car intended to emphasize systems which are practicable now or will be in the immediate future. The structure is unmodified. These systems will be described in detail this afternoon and I will just summarise them now:

- Automatically retracting lap and diagonal seat belt
- 4-wheel anti-lock brakes and total mobility tires
- Head-up display of speed
- Low cost self-levelling headlights and headlamp cleaning
- Auto-Sensa automatically shaded projector lamp
- Automatic anti-dazzle rear view mirror
- Vehicle condition monitor, and
- Dual intensity rear lighting

CONTRACTS

Regarding progress on contracts, substantial contracts have been placed by government with industry against the Transport and Road Research Laboratory's research program which is in TRRL leaflet LF 316 on page 90 of the orange booklet. The total value of contracts placed to date is approximately £0.75m with further contracts in the discussion stage.

Following a large scale trial of anti-lock devices on articulated goods vehicles the U.K. is planning to carry out a trial of current production cars equipped with non-locking brakes. To obtain a reliable answer within a reasonable time the trial will need to be mounted on a large scale and will depend for success on the cooperation of many people and organizations. However, if carried through it will represent a major initiative towards establishing a case for or against the adoption of non-locking braking systems for cars.

Other European countries are actively working on non-locking brakes and in recent discussions representatives of France, Sweden, Italy and the U.K. agreed to collaborate on this subject.

RESEARCH ON SAFETY STANDARDS

In January 1972, the Department of the Environment in Britain announced its intention of moving towards performance-based rather than design-based standards for vehicle safety. A particular field of interest is that of occupant protection where a performance-based standard should provide greater freedom for designers while ensuring that the overall system will provide the required occupant protection.

IMPLEMENTATION OF RESEARCH

It is quite clear that several major issues bear on the safety solutions which will eventually be applied to production cars. These include:

1. The types and severities of impacts to be catered for in car design
2. Human tolerance levels
3. Representation of the human body for test purposes

The international character of the ESV program has already highlighted some areas where it should be possible to agree internationally on criteria and others where there are fundamental differences between countries which have to be recognized. In common with many other countries we need small cars and these cannot carry large space or weight penalties; furthermore, we have a considerable pedestrian safety problem involving cars. Our program therefore is based on achieving the best safety solution not only for the occupants of all the vehicles involved in a collision but also for any pedestrians involved. For this reason we place considerable emphasis on accident and injury analysis to guide our efforts.

For example, British studies suggest that 85% of frontal impacts on our roads would be encompassed by a rigid barrier test at 30 miles per hour and that there are rapidly diminishing returns from meeting higher speed requirements. Furthermore, the need to cater for pedestrians means providing a relatively soft front section which will to some extent reduce the ultimate rigid barrier performance for a given available length. Additional structural modifications will be required to the fronts of vehicles to prevent pedestrians being thrown down into the road after being struck. A compromise will therefore have to be made in our case between the somewhat competing claims of vehicle occupants and of pedestrians.

The development of occupant protection systems depends crucially on the means used to represent the human body. In Britain studies relating injuries to the deformation of vehicle parts struck by the occupant are enabling human tolerance levels to be deduced from actual accidents. This is one area where it ought to be possible to reach agreement internationally and thus greatly facilitate car safety work but at the present time considerable differences of opinion appear to exist and we would welcome within this joint ESV program the setting up of an international task force of specialists to resolve the differences.

A similar problem exists in providing a low cost representation of the human form for test purposes and this too might be a suitable subject for special action. And finally Mr. Chairman, may I express the willingness of every member of the British team to respond to any questions about our program which it's within our power to answer.

ITALY

MR. GAETANO DANESE, *Director*

Rome Motor Vehicle Testing Center, Ministry of Transport

Ladies and Gentlemen

May I first of all thank the U.S. Federal Department of Transportation for the excellent arrangements made for this Third Technical Conference on Safety Vehicles, and for extending an invitation to attend to the Italian Ministry of Transport which I have the privilege to represent.

In my opinion, this Conference, over and above its unquestionable technical and informational value, commends itself for allowing a useful comparison of the progress made by the various participating countries in the field of automotive safety, as well as for clearly showing the interest that the safety issue arouses on the part of manufacturers, public opinion and governmental agencies everywhere.

As you may have noticed on previous occasions, Italy is extremely concerned with this problem, not only because of the high ratio of motor vehicles to the population and the number and seriousness of traffic accidents, but also because a failure or even an unjustified delay in solving the issue of safety might have an adverse effect on the steady social and economic progress of the country.

The Italian Ministry of Transport has taken the lead in advocating, at the national and international levels, some important and meaningful measures aimed at placing this problem in its proper frame and perspective, keeping in mind the objectives to be achieved and the funds and technical know-how available.

Italy has welcomed the establishment of the European Committee for Experimental Vehicles and signed the Memorandum of Understanding with the U.S. Government in the firm belief that the key to a comprehensive and possibly decisive advance toward the solution of the universal problem of motor car safety can only be found in international cooperation.

At the Italian domestic level we have established a program, already illustrated at the Stuttgart Conference in October last year, which covers the whole range of tasks entrusted to Italy by the European Committee. The subjects it includes are wide in scope and fairly ambitious, and perhaps a critical appraisal would be necessary to make the program more effective and realistic. While ours, as every other country, has of course its own interests to protect, it will nevertheless help, to the best of its ability, to attain common goals for the benefit of all.

I should like to emphasize here a special element introduced by the Italian Ministry in this work. The Italian program, as is the case elsewhere, avails itself of the cooperation of industry and of the experience of specialized research institutions, but the Ministry itself acts as the protagonist, not only in charge of coordination but also of actual research and testing. The importance of the subjects to be dealt with has suggested this approach, which in my opinion clearly shows the interest taken by the Italian Government in this matter.

Moreover, our Ministry of Transport has an established tradition in directly promoting research in various technical fields, and I feel it is quite adequately endowed with technical know-how, equipment and staff and can expect satisfactory results.

Our work has had a good start in several directions, concentrating more particularly on passive restraint systems (including the design of a new type of seat) which may, in our view, effectively contribute to passive safety of vehicle occupants in case of collision.

I cannot deny that we are confronted with manifold difficulties, but I trust they will be overcome and our goals will be attained.

Lastly, I should like to publicly acknowledge the most laudable fashion in which Italian industry has been carrying out its part of the program ahead of the original schedule. Industry's presentation at this Conference, as well as at the Transpo '72 Exhibition, will prove this. Its research is already yielding concrete results which will surely contribute to point the way to be followed in reaching our desired safety objectives.

FRANCE

MONSIEUR MICHEL FRYBOURG, *Director*

Institute of Transport Research, Ministry of Transport

The improvement in traffic safety is a common objective for us all. The task to be undertaken in relation to the automobile involves parallel efforts at technical innovation, common action and economic controls.

The French Government brings its entire contribution to this Third International Conference which will reaffirm the possibilities of common action uniting governmental administrations and automobile manufacturers, both of which are convinced of the importance of the objective.

TECHNICAL INNOVATION

Although it is but one of many elements of a total strategy for highway safety, the ESV program is of great importance to France. Because it is concerned with the vehicle itself, with crash protection, the program has an essentially engineering orientation, and has its roots in the promotion of technological innovation.

This point needs stressing. At a time when efforts to develop new systems of transportation are accelerating in many countries, the relative stability of automobile technology — in the eyes of the public, at least — might lead one to believe that this technology has lost its momentum, that it is incapable of further progress. It is not so. We, in the French administration, are convinced — and I do not doubt that the papers we are going to hear will confirm it — the automobile industry has still very strong capacity for innovation, and its know-how will greatly contribute toward making future generations of vehicles much safer.

One can already state with confidence that maneuverability characteristics, so important for active safety, have already reached a high degree of perfection in Europe, and will be improved to an even higher degree.

One can likewise predict great improvements in passenger protection.

A new, and until now little known aspect of safety will assume importance: that of "on-board safety," that is, devices which will help drivers to avoid wrong decisions and prevent them from acting dangerously.

JOINT ACTION

The French Government believes that the efforts will be more productive if joint action in this field is frank and widespread.

It is important in these efforts, which involve the industry and governments at the national and international level, to define the rules of the game.

One could summarize this as follows: the government defines the objectives; the automobile industry strives to attain these objectives; the countries with the most initiative show other nations the path to follow.

Realistically, this simplified pattern must be qualified by certain conditions.

As regards international relations, countries should not use their regulatory authority unilaterally. This would not only be contrary to the rules of the Common Market which aim to remove barriers to trade between member countries, but also work against healthy competition which must be stimulated on a world scale in order to extend the benefits of the automobile to a wide range of consumers. Also, the relations between nations must not become ones of domination or confrontation. We should actively and peacefully seek useful exchanges, conscious that the rules of competition forbid that everyone feel the sole master in his country. Otherwise one would be entitled to feel that protectionism hides behind the safety issue — a goal which all of us seek for the benefit of all.

Another condition of this joint action is that the objectives that are pursued be realistic: one must reconcile what is technically possible with what is socially desirable. After the criticism voiced about the performance characteristics of the experimental safety vehicle, I believe that we all agree about the need to improve the evaluation testing which determines the safety of a vehicle. In this regard, I wish to recall the importance which the French delegation attaches to the criterion of "aggressivity" which becomes important, now that the automobile fleet in all countries tends to be heterogeneous, with the largest cars being two, sometimes three times as heavy as the smallest ones. The global aspect of the automobile market makes it necessary for us to distribute in an optimal fashion the chances of passenger protection and survival in cars of different sizes.

ECONOMIC CONTROLS

We should also realize that innovation and joint action are not an end in themselves. They should not act as substitutes for the market mechanism; rather they should form part of it and complement it, in order better to adapt the product — the automobile — to the needs of the community. We have appreciated the message of the RECAT report which analyzes the impact of regulatory controls.

The difficulty lies in that one must reconcile relatively rigid regulations with social needs and social costs — costs which can vary with the geographic, social, economic and cultural conditions in each country.

We must not forget that all regulatory actions which affect vehicle weight will likewise affect its size, a characteristic important for those cars which must negotiate the narrow streets of European cities.

We must pay attention to accidents in city streets which occur at slower speeds than those on open highways, but which involve more frequently pedestrians and cyclists.

We must keep in mind national differences in personal income and in level of motorization — differences which are considerable from country to country.

We must also make sure that the resources required for the effort do not eliminate from competition smaller firms which are often among the most innovative ones.

Technological progress and international cooperation must form part of a dynamic policy of improving the automobile and its control. They must be oriented toward the needs of a consumer who increasingly uses his auto in an urban milieu, and to whom governments cannot, through excessive zeal, refuse access to automobility.

AN OPTIMISTIC CONCLUSION

Although the French delegation had justifiable fears at the outset of this program, it faces the future of this effort with optimism.

The French Government will support fully an effort which will adapt technological development, international cooperation and the regulatory process to the needs of society and the different conditions in various countries.

SWEDEN

MR. GUSTAV EKBERG, *Head of Vehicle Department*

Swedish Road Traffic Safety Office

Mr. Chairman, ladies and gentlemen.

At the Second International Conference in Germany, seven months ago, I expressed the hope that Sweden in the future would be able to contribute to the development of the ESV program.

I am very happy to announce that Sweden and the United States, in March of this year, signed a memorandum of understanding concerning exchange of information on the development of Experimental Safety Vehicles.

With this agreement, Sweden has joined the Federal Republic of Germany, France, Italy, Japan, the United Kingdom, and the United States, which earlier had formed a group of countries sponsoring safety vehicle development.

The Swedish Government intends to initiate a subsystems study related to the ESV project with the aid of Swedish car and component manufacturers as well as the research community.

The aim of the Swedish program is to develop in practical engineering form car safety features designed to prevent vehicle crashes or to offer high levels of protection to vehicle occupants in crashes.

The program will be related to vehicles in weight classes common in Sweden, thus to say about 3,000 pounds. The Swedish Board for Technical Development, which is a governmental agency, and the two Swedish car manufacturers, Saab and Volvo, have jointly decided to initiate a research project which is called "Steerability during Emergency Braking." This project covers, among other things, evaluation of anti-skid brake systems, and the aim is to propose performance standards and test procedures for such systems.

A technical presentation of the project will be given at tomorrow morning's session.

In addition the Volvo Company has recently announced the completion of an experimental safety car. The session tomorrow will include a detailed presentation of the design.

May I also be permitted to express my great satisfaction and my gratitude to the Department of Transportation for their invitation to this conference which gives me the opportunity to address such a highly qualified audience in this beautiful city, that is not only the capital of the United States but also has played such an important role in establishing international cooperation for the development of safer vehicles.

Thank you.

BELGIUM

MR. PAUL NICOLAS, Ing. U.I.Lv., *Director of Administration*

Transportation Administration, Ministry of Communications

Even though statistically we might find that Belgium is a country that exports cars and trucks, the figures refer to products of assembly factories where the capacity greatly exceeds the demands of the national market. Capacity and need are integrated, however, in the production networks of the big automobile companies that assure the world-wide distribution of their products.

The Belgian assembly factories do not maintain many research units or important study centers. The Government, therefore, has not been able to call on the automobile industry of the country to actively participate in the world-wide Experimental Safety Vehicle Program. But the authorities are far from disinterested; they are attentively following the efforts undertaken in various European countries to design experimental safety vehicles or to study in more detail one safety element or another. They were pleased with the results of coordination attributed to the European Committee on Experimental Vehicles — European Experimental Vehicles Committee (EEVC).

Recently, the Committee decided to get involved in air pollution caused by engine exhaust. We could only be pleased by this program extension since the elimination of the toxicity of engine exhaust is certainly also an important factor of safety.

The Belgian Government actively supports the work of a number of study groups and has let research contracts in the safety area with specialized organizations.

By their position in the center of Europe and the ready comparison of technical characteristics of vehicles of all nationalities assembled in their territory, the Belgian automotive engineers are particularly well informed to actively participate in the international study projects in the area of auto safety.

Everything depends on three factors: road, driver and vehicle, but before cooperating to assure traffic safety, the Study Center for Road Safety devoted an important part of its material and personnel resources to the study of different vehicle behavior. The Study Center, under Government request, has particularly undertaken tests of motorcycle helmets and vehicle noise measures. Work on noise led the Study Center to propose to ISO/TC22 a revision of the Recommendation R362 and to furnish to the Belgian authorities the elements justifying Geneva intervention in order to amend Rule 9 of the European Economic Commission (C.E.E.). The proposal calls for measuring noise under vehicular operating conditions that are more realistic and would measure all engines under practical circumstances, for instance when in urban traffic, engine noise adds to environmental pollution.

The Royal Military Academy, in Brussels, under the dynamic leadership of professor E. Sibenaler, has been concerned for many years with the toxicity of vehicle exhaust fumes. It is now fully equipped for measuring the amount of carbon monoxide, hydrocarbons, and nitrous oxides and it has been charged by the Government to conduct compliance tests according to Rule 15 of Geneva. Delegates of this specialized laboratory regularly meet with their colleagues from other countries to exchange information based on the experience gained during the course of the tests and to refine the methods of analysis, in order to assure greater reproducibility. This is more important than we can imagine because soon the demands of Rule 15 will become more stringent and because the quantities of deleterious components to measure will become smaller.

In the past, the Group of organizations of automobile registration — (GOCA) has usefully participated in the study of the opacity of Diesel engine fumes. Under its direction, the test method has been refined and made precise and the measuring devices have been arranged to better reflect the physical characteristics of the measuring column of gas. In fact, these studies were originally to be part of work conducted recently on Rule 24 of Geneva. The authorities now use a precise devise allowing them to objectively establish the state of the regulation . . . or irregularity of a diesel engine. We will be satisfied to watch to make sure that users respect the limits imposed by the authorities in order to eliminate exhaust producing engines from the road.

The Belgian authorities are nevertheless aware that internal combustion engines are not necessarily the unique solution that should be applied for the whole world. No, recently a day of information on the electric vehicle was held in Brussels. It allowed those interested to show the present state-of-the-art, to display and publicize the undeniable progress accomplished over the last few years, to measure the road still to come before delivering an operational electric car that would be at the point of being able to take up the place of the gasoline-run vehicle.

We can only cite by memory here the activities of the National Institute of Glass. During the preceding conference, we discussed fully the Belgian contribution to the focus on safety glass.

If there is a particularly important area in traffic safety, it is most likely automobile lighting. Since much before the ESV craze of the last few years, the national Belgian committee on lighting joined the secretariat with a mixed study group, "The International Lighting Commission — International Standards Organization." It deals with the Working Group "Brussels 1952" better known by the initials G.T.B., that just celebrated in Brussels the twentieth anniversary of the beginning of its work. Displaying an untireable activity almost unique in the annals of international organizations, the G.T.B. is at the bottom of numerous initiatives in the area of automobile lighting. All the aspects of lighting and signalling are constantly being reviewed and notable progress such as European asymetrical headlights, halogen headlights, higher intensity signal lights carry the G.T.B. mark. Carrying the status of consultant to the C.E.E. in Geneva, the G.T.B. regularly submits regulation projects for improving vehicular safety by better signalling and a more efficient lighting system. Of some 27 rules already published by the C.E.E., 12 concern automobile lighting. And at the recent plenary session in Brussels, five supplementary projects were approved with the aim of transmitting them to Geneva. They concern lamps for rear signal devices for fog, warning lights, side signal lights and cleaners for the glass of the lights.

Furthermore, Belgium was the first country in Europe, if not the world, to develop a standard on lighting, and make its application mandatory. Since January 1, 1968, it has been prohibited in Belgium to sell non-conforming devices, or to meet the lighting rule with such non-conforming devices.

It is therefore quite evident that even if Belgium is not involved in the activity of constructing automobiles justifying the signature of a bi-lateral agreement to exchange information, Belgium nevertheless is involved in much technical activity in the very different areas directly related to vehicle safety.

That is why I wish to particularly thank the organizers of this conference for having asked Belgium to participate.

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- Comparison of the Aggressiveness of Different Vehicles and the Safety They Afford
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- Experimental Safety Subsystem Citroen Program
- Progress Report on the Citroen Experimental Safety Subsystem Program
- Homogeneous Safety Amid Heterogeneous Car Population
- French Developments of Restraints Means
- Critical Review of ESV Program Technical Trends and of Future Resulting Legislation

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- Driving Aids
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- The Total Mobility Tire
- Anti Locking Brake Development in the United Kingdom
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THE FRENCH TECHNICAL PRESENTATION

SECTION 2 PART 1

INTRODUCTION

MR. MICHEL FRYBOURG, *Director*

Institute of Transport Research, Ministry of Transport

Thank you, Mr. Chairman.

The French report will consist of three parts. We will first hear a review by Mr. Leroy, who is the Director of the Laboratory of Impacts, which belongs to the National Organization for Road Safety.

The second part will address particularly the work done by the Citroen Company. And the third part will include presentations of the research done by the Association of Peugeot-Renault. Therefore, I will immediately recognize Mr. Leroy of the National Organization of Road Safety.

Mr. Leroy will speak on the "Aggressiveness of Vehicles."

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COMPARISON OF THE AGGRESSIVENESS OF DIFFERENT VEHICLES AND THE SAFETY THEY AFFORD

MR. CLAUDE BERLIOZ

Organisme National de Securite Routiere

AREA OF STUDY

The purpose of this study is to compare different vehicles, by making the distinction between various classes of passenger cars.

On the one hand, we consider, in the personal injury accidents where they are involved, the damage inflicted on the pedestrians or the occupants of the other vehicles, which constitutes the study of their aggressiveness; on the other hand, the damage inflicted on their own occupants, which constitutes the study of their safety.

This study relates to the 221,000 personal injury accidents recorded in France in 1969 by the "Gendarmerie Nationale" and the "Surete Nationale" which had killed 14,700 people of whom 50 percent were in passenger cars, 25 percent on two-wheelers and 21 percent pedestrians.

In order to eliminate a possible effect of the occupancy-rate of vehicles, only the state of the drivers (or pedestrians) is taken into account, according to the categories: killed, seriously injured, slightly injured, uninjured.

To be considered as killed the victims must have died within 6 days following the accident, and as seriously injured the victims must have stayed in the hospital more than 6 days.

METHOD

We have characterized different classes of agents involved in personal injury accidents as follows:

1. The pedestrians.
2. The two-wheelers which are mainly constituted in France by motorcycles with engine displacement inferior to 50 cm^3.
3. The passenger cars.

This class is first divided into two subclasses:

1) The French passenger cars of great diffusion patterns.
2) Other passenger cars. This subclass includes the French passenger cars of small diffusion patterns and the foreign cars.

Then, the first subclass is split into seven groups according to the design criteria, to those of the weight and to the seniority of the conceiving:

a) "former rear-engine car", (F.R.E.), i.e. which production had stopped in 1969 and which weight is between 560 kg and 670 kg and the top speed between 95 km/h and 115 km/h.

b) "new rear-engine car", (N.R.E.), i.e. still produced in 1969, which weight is between 700 kg and 795 kg and the top speed between 125 km/h and 135 km/h.

c) "very light front-wheel drive"*, (V.F.W.), which weight is between 495 kg and 725 kg and the top speed between 85 km/h and 125 km/h.

d) "light front-wheel drive"*, (L.F.W.), which weight is between 805 kg and the top speed between 138 km/h and 142 km/h.

e) "middle front-wheel drive"*, (M.F.W.), which weight is between 980 kg and 1400 kg and the top speed between 140 km/h and 175 km/h.

f) "former classical propelled car", (F.C.P.), which weight is between 930 kg and 1190 kg and the top speed between 115 km/h and 135 km/h.

g) "new classical propelled car", (N.C.P.), which weight is between 960 kg and 1200 kg and the top speed between 130 km/h and 160 km/h.

4. Vans, i.e. commercial vehicles of full weight inferior to 3, 5 T.
5. Trucks and other vehicles.

The accidents are regrouped into different classes according to the agents involved and defined above.

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*All "front-wheel drive" are new patterns, i.e., still produced in 1969.

- single-vehicle accidents without pedestrian
- accidents involving two agents which include as many classes as number of ways of choosing two classes of agents.

We do not know, in these accidents whether the main crash was between both these agents or with a fixed obstacle, hit by one of the vehicles after having struck the other agent. Yet, the probability that a fixed obstacle had been hit in these classes of accidents is less than in classes of single-vehicle accidents without pedestrian.

- accidents involving more than two agents.

At least, we have characterized the accidents that occur on highways outside built-up areas, because we wanted to eliminate the possible influence that the more urban character of certain classes of cars might have upon the outcomes.

The total conciliation between the aggressiveness and the safety of a class of vehicles was noted by means of the aggressiveness-rate in fatal accidents, ratio of the number of pedestrians or other vehicles drivers (external victims) which were killed in the accidents involving this class of vehicles, to the number of killed drivers in this last class (internal victims).

The statistical significance of the differences observed is noted by means of χ^2 tests which compare the distributions of internal and external victims according to the different agents.

The analysis of the relative aggressiveness of two classes of French passenger cars of great diffusion patterns is made by having the numbers of casualties (killed or seriously injured) among drivers in the two classes compared to each other, and that in accidents involving both of the agents which represent a vehicle of each class. The statistical significance is analyzed by means of χ^2 tests (df = 1) by uniforming the numbers of drivers involved (same amount for the two classes).

The safety level afforded by a class of vehicles is noted by means of death-rate and casualty-rate of drivers in three types of accidents:

- single agent accident (i.e. involving one vehicle without pedestrian)
- accident involving two agents, the other being a passenger car or a van
- accident involving two agents, the other being a truck.

The statistical significance of the differences of the rates observed between the classes is analyzed by means of χ^2-tests on the distributions of casualties and involved people.

MAIN RESULTS

Aggressiveness rates

The differences in the frequencies of internal killed drivers and external killed drivers according to the classes are highly significant as well on highways as on the whole of France (table 3).

The two-wheelers and the pedestrians have obviously the weakest rate values, and the trucks the strongest (8 or 9 times higher than for passenger cars). On highways, this rate value is about three times higher for the two passenger cars classes that are the speediest and heaviest ("middle front-wheel drive" and "new classical propelled car") than for the three classes that are the least speedy and lightest ones ("very light front-wheel drive", "former and new rear-engine cars"). The differences are less marked on the whole of France.

Relative aggressiveness between passenger cars on highways

27 percent of passenger car drivers are killed in crashes between passenger cars in the whole of France, 40 percent in single-vehicle crashes and 22 percent in crashes against trucks (table 1). On highways, the 27 percent become 29 percent (table 2).

Among the pairs of French passenger car classes of great diffusion patterns, some give a strong dissymmetry in the distribution of casualties concerning the drivers of two classes of vehicles, in crashes involving them both (tables 4 and 5). Thus, in crashes involving a "very light front-wheel drive" and a "new rear-engine car", we may note among the drivers of the former 118 casualties for 70 among those of the latter, difference highly significant (,01).

The six pairs corresponding to crashes involving a "middle front-wheel drive" or a "new classical propelled car" and a "very light front-wheel drive" or a "former or new rear-engine car" give all of them a highly significant dissymmetry. The casualties, in these crashes, are about three times out of four in the lightest and the least speedy vehicles.

The casualty-rate of drivers of "very light front-wheel drives" is twice weaker when the crash occurs against another "very light front-wheel drive" than when it does against a "middle front-wheel drive."

Safety of Passenger car drivers (tables 6,7,8,9)

a) in crashes with passenger cars and vans

The death-rates and the casualty-rates are in general higher for the classes which relative weak aggressiveness has been mentioned above.

b) in single-vehicle crashes without pedestrian

The death-rate and the casualty-rate are slightly higher on highways than in the whole of France (about 15 percent) and appreciably proportional for the different classes of vehicles.

On highways, the death-rates are for the two least speedy classes though they were the lightest ("former rear engine car" and "very light front-wheel drive"), about twice weaker than for the three speediest ones ("new classical propelled cars", and "light and middle front-wheel drive"). These differences are highly significant (.01). The results according to the casualty-rates are the same but the differences are more reduced.

c) in crashes with trucks or similar

The death-rates, on highways, are the highest for the rear-engine cars, may be more vulnerable to the embedding phenomenon, and about twice stronger than they are for the heaviest class (differences highly significant for the "former rear-engine cars" and the "middle front-wheel drives").

CONCLUSION

The results observed in France are identical to those observed in Italy and presented at the Stuttgart Conference by Mr. A. Margara. The fact that the cars the most vulnerable in crashes with other vehicles, are the least vulnerable in those with fixed obstacles occurring on the same type of roads (highways) and, vice-versa, shows that the rules of the secondary safety can't be seriously made without taking the ways of using and the riding speeds into account (correlated to the afforded speeds as the measures done in France had shown). The greatest care must be then taken in the regulation of the matter in order to avoid the possible risk of eliminating the vehicles of little aggressiveness which could offer a better safety when they are not met with more aggressive vehicles.

TABLE II

KILLED DRIVERS OR PEDESTRIANS CLASSIFIED ACCORDING TO THE VEHICLE CLASS CONDUCTED AND TYPE OF ACCIDENT ON RURAL HIGHWAYS IN FRANCE IN [illegible]

Vehicle class conducted	TYPE OF ACCIDENT						
	Single vehicle accident without pedestrian	Accident involving two agents, the other being				Accident involving more than two agents	TOTAL
		Pedestrian	Two wheeler	Passenger car or van	Truck or similar		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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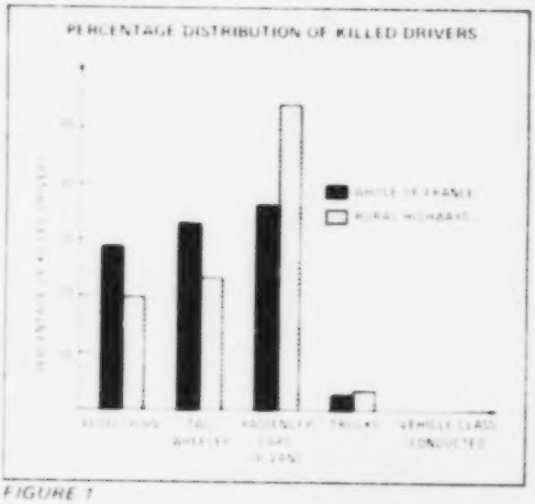

FIGURE 1

TABLE III

NUMBER OF INTERNAL KILLED DRIVERS (I) AND EXTERNAL KILLED DRIVERS (E) CLASSIFIED ACCORDING TO THE VEHICLE CLASS CONDUCTED IN CRASHES INVOLVING TWO AGENTS IN FRANCE IN [illegible]

Vehicle class conducted	Whole of France			Rural Highways		
	Internal killed drivers	External killed drivers	Aggressiveness rate	Internal killed drivers	External killed drivers	Aggressiveness rate
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]

[illegible]

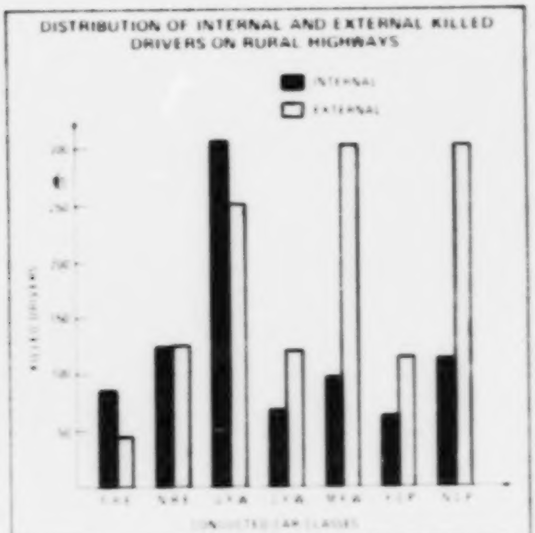


FIGURE 2

[illegible]

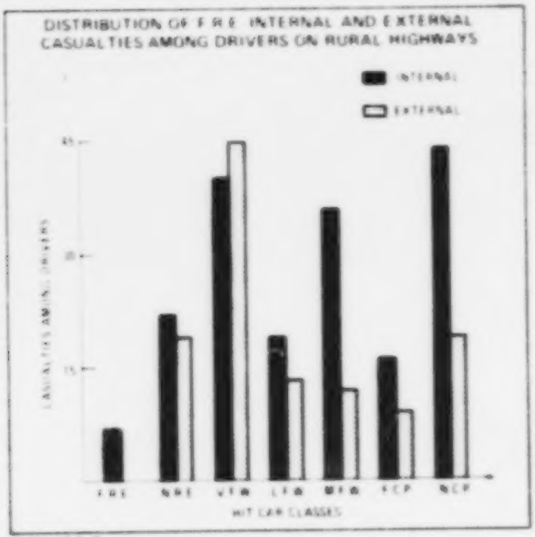


FIGURE 3

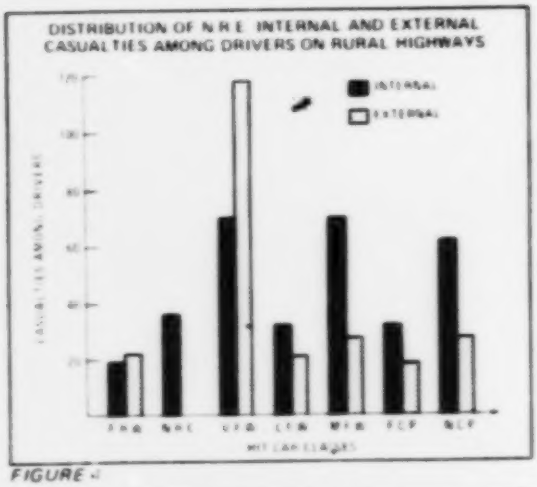


FIGURE 4

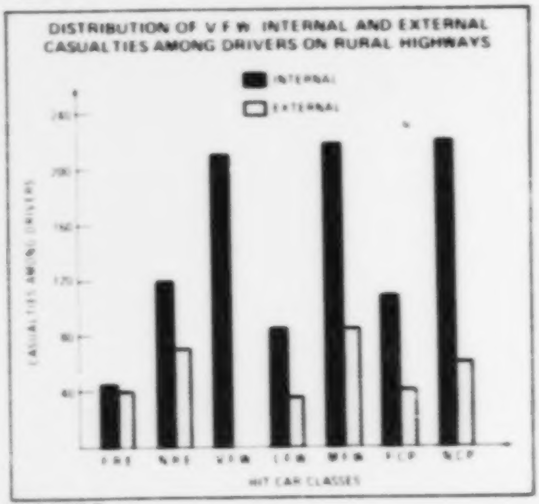


FIGURE 5

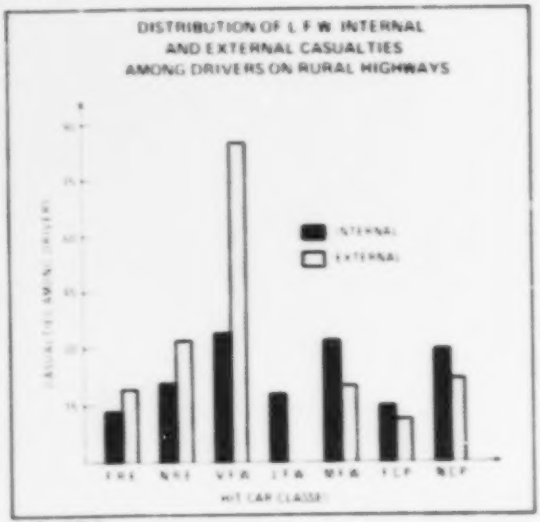


FIGURE 6

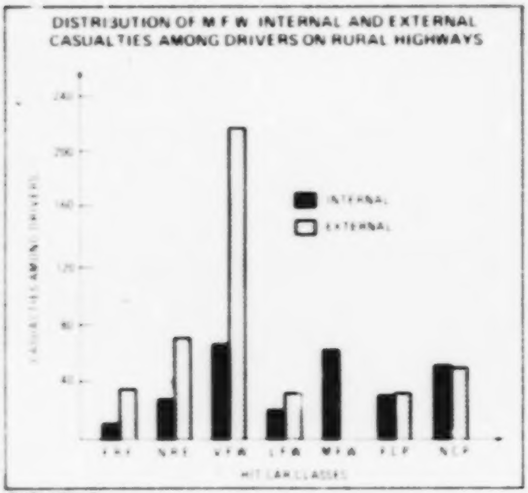


FIGURE 7

TABLE 5

CASUALTY RATE OF DRIVERS INVOLVED IN CRASHES BETWEEN TWO FRENCH PASSENGER CARS OF GREAT DIFFUSION PATTERNS ON RURAL HIGHWAYS IN FRANCE IN 1980 CLASSIFIED ACCORDING TO THE VEHICLE CLASS CONDUCTED

WE FIND IN THE CELL (LINE i, COLUMN j) THE CASUALTY RATE OF DRIVERS OF A i VEHICLE CLASS IN CRASHES INVOLVING AN i VEHICLE CLASS AND A j VEHICLE CLASS

French passenger car of great diffusion patterns	Former rear engine car	New rear engine car	Very light front wheel drive	Light front wheel drive	Middle front wheel drive	Former classical propelled car	New classical propelled car
Former rear engine car	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
New rear engine car	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Very light front wheel drive	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Light front wheel drive	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Middle front wheel drive	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Former classical propelled car	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
New classical propelled car	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

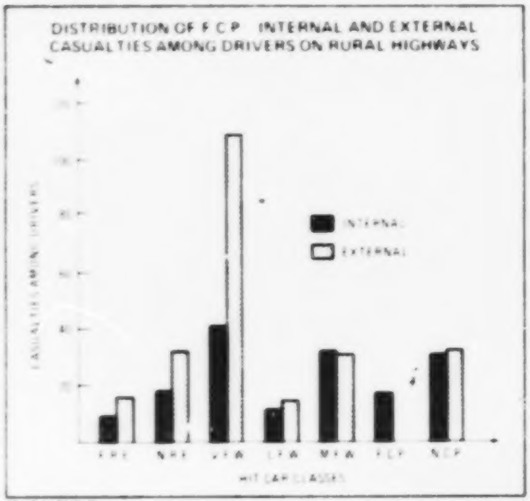


FIGURE 8

TABLE 6

DEATH RATE OF DRIVERS OF FRENCH PASSENGER CARS OF GREAT DIFFUSION PATTERNS CLASSIFIED ACCORDING TO THE VEHICLE CLASS CONDUCTED AND TYPE OF ACCIDENT ON THE WHOLE OF FRANCE IN 1980

	TYPE OF ACCIDENT								
Vehicle class conducted	Single vehicle accident without pedestrian			Accident involving two vehicles without pedestrian, the other being:					
				passenger car or van			truck or lorry		
	killed	involved	rate	killed	involved	rate	killed	involved	rate
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

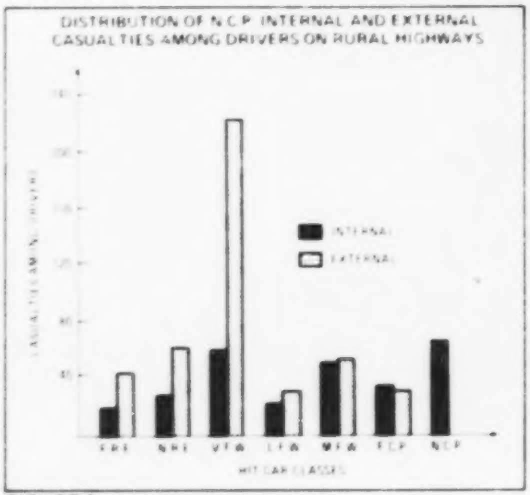


FIGURE 9

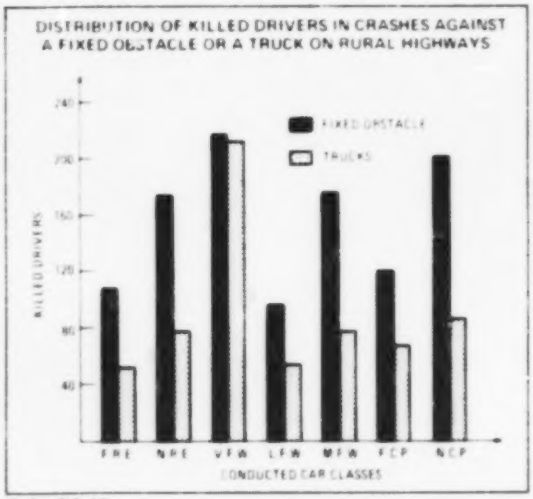


FIGURE 10

TABLE VII

CASUALTY RATE OF DRIVERS OF FRENCH PASSENGER CARS OF GREAT DIFFUSION PATTERNS CLASSIFIED ACCORDING TO THE VEHICLE CLASS CONDUCTED AND TYPE OF ACCIDENT ON THE WHOLE OF FRANCE IN [illegible]

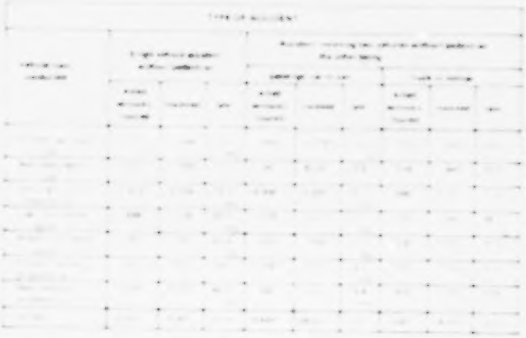

TYPE OF ACCIDENT
Vehicle class conducted
Single vehicle accident without pedestrian
Accident involving two vehicles without pedestrian as the other being
passenger car or van
truck or vehicle
killed seriously injured
involved
rate

TABLE VIII

DEATH RATE OF DRIVERS OF FRENCH PASSENGER CARS OF GREAT DIFFUSION PATTERNS CLASSIFIED ACCORDING TO THE VEHICLE CLASS CONDUCTED AND TYPE OF ACCIDENT ON RURAL HIGHWAYS IN FRANCE IN [illegible]

TYPE OF ACCIDENT
Vehicle class conducted
Single vehicle accident without pedestrian
Accident involving two vehicles without pedestrian as the other being
passenger car or van
truck or vehicle
killed
involved
rate

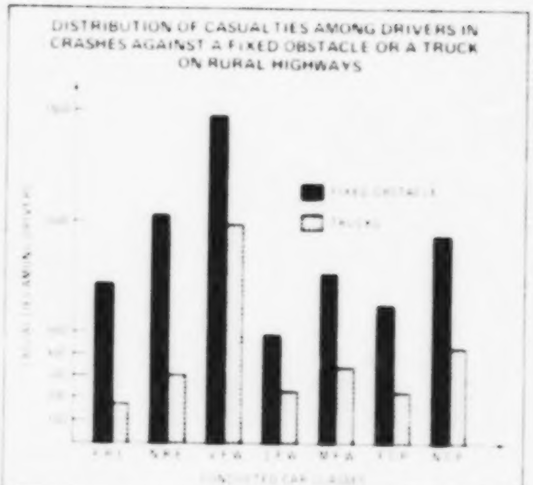
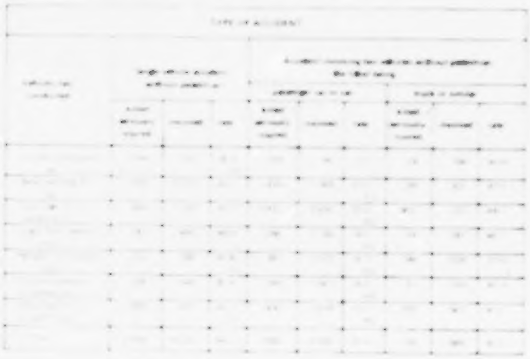

DISTRIBUTION OF CASUALTIES AMONG DRIVERS IN CRASHES AGAINST A FIXED OBSTACLE OR A TRUCK ON RURAL HIGHWAYS

FIGURE 11

TABLE IX

CASUALTY RATE OF DRIVERS OF FRENCH PASSENGER CARS OF GREAT DIFFUSION PATTERNS CLASSIFIED ACCORDING TO THE VEHICLE CLASS CONDUCTED AND TYPE OF ACCIDENT ON RURAL HIGHWAYS IN FRANCE IN [illegible]


TYPE OF ACCIDENT
Vehicle class conducted
Single vehicle accident without pedestrian
Accident involving two vehicles without pedestrian as the other being
passenger car or van
truck or vehicle
killed seriously injured
involved
rate

STUDY ON THE INJURIES OF THE INFERIOR MEMBERS DUE TO ROAD ACCIDENTS

MR. J. LEROY, *Director*
Laboratoire des Chocs, O.N.S.E.R.

INTRODUCTION

Multidisciplinary investigations allow us to evaluate the relative importance of road safety problems. But, dealing with essential subjects, that is, protection of head and chest, it is most important to remember that certain injuries which, if they do not lead to death, may conserve, despite the safety devices already made, a functional and social cost not to be neglected.

It is for this reason that we are about to deal with the injuries of the inferior members and particularly with the distal segment. It is not a question of anatomical limit but it is a combination including the ankle joint and the lowest third of the shin-bone and of the splint-bone which constitute a functional combination and undergo injuries connected to the same mechanisms.

Functional combination studied in this paper.

Which are the mechanisms causing these injuries?

Involuntary rotations of the foot either by wedging between the pedals or in the folds of the car floor.

The rotative movements being extremely limited, any form of excessive movement ends in a fracture either at the level of the tibio-tarsal joint, or, if the foot is squeezed lower down, in dislocations of the foot with frequent fractures of the metatarsals.

A compression of the foot can arise. This occurs especially when the driver has his legs spread out or his knees squeezed under the dashboard. The reverse movement of the floor and pedals or even the simple motion of the foot breaking desperately, can create certain injuries only due to compression which can break the astragalus as well as the extremity of the shin-bone and the splint-bone.

AETIOLOGY

Since 1969, we have been leading a bidisciplinary investigation on road accidents of which the main aims are to define the correlation between occupant injuries and vehicle deformation, to precise energy level, to verify the effectiveness of safety devices and to build up our knowledge of human impact tolerance.

We have noticed that little more than 5% of injured people suffer from foot injuries, dislocations or fractures mainly being open. About 10% of these wounds present bilateral injuries.

Almost 80% of these people were drivers. This clear predominance explains itself:

1. because numerous vehicles have only one occupant
2. because of the pedals' existence
3. by the deformation of the floor or by the introduction of wheels often being more important on the driver side, since 40% of these impacts are on the left front side.

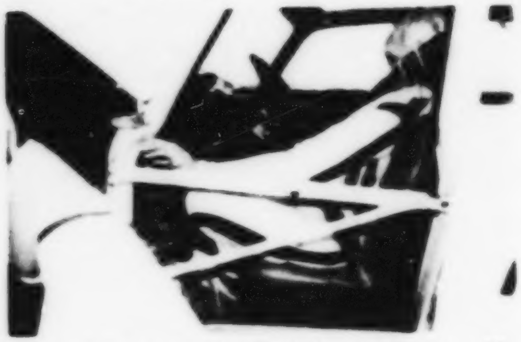
What are the vehicle's structures causing these injuries?

Outside view of the VW 1300 (lateral impact, fatal injury).

View of the pedals (we can notice the shoes of the driver squeezed between the pedals).

The pedals can effect in two ways, either by imprisoning the driver's feet when in twisting motion or due to the fact that the driver attempting to save himself pushes his feet down on the pedals which, during the impact, literally project the foot bones into articulation.

Outside view of the left foot of the driver (dislocation under the astragalus).



Crash test on barrier (Peugeot 204 – v 50 kmh – 30 on the left). The feet of the dummy are squeezed by the reverse movement of the pedals and of the wheel arch.

The floor's deformation is of great importance in the pedals rejection as well as for its own action. Frequently we can indice very evident folds which swell the floor's formation causing wounding fractures brutally contacting the occupants' feet.

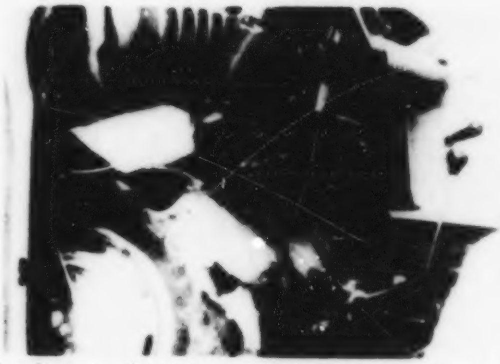
This was clearly shown in several vehicles where the driver and passenger both showed feet injuries, occasionally bilateral.

We will here give a typical example. Driver and passenger were wearing three point safety belts during a particularly violent frontal impact: the floor was deformed. The driver showed only a right astragalus fracture, and an ankle-bone dislocation with a left splint-bone fracture without any other injury. The passenger was suffering from a left ankle-bone fracture.

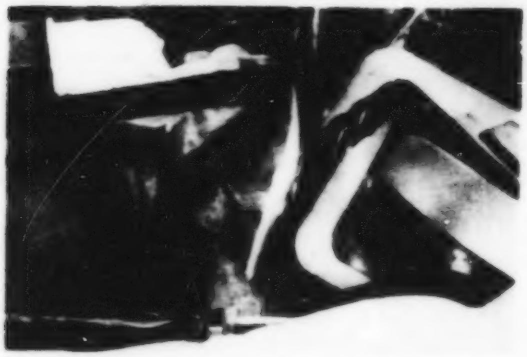
Another factor causing the inferior members injuries is the introduction of wheels. This mechanism is only to be found in very serious impacts but feet injuries are most concurrent.

Thus, we examined a vehicle after a very violent frontal impact. The passengers were restrained and only the passenger whose side was entered by the wheel and the body destructed by this introduction

Citroen Ami 8. Frontal crash in another vehicle, then rollovers.



Inside view – Introduction of the left front wheel.



Floor deformation in front of the front occupant.

Peugeot 504 – Frontal crash on the left side in the side of this van.

Outside view – Renault 12 which crashed in a post.

Inside view – Deformation of the wheel-arch pushed by the left side front wheel.

has to suffer from very serious bilateral injuries of the two inferior members.

The wheels are one of the strongest elements in the car body. If, during a frontal impact, the front wheels push the beam floor backwards they act very well with the compressive force and they limit the deformation, but the wheels are in this situation only if they are not deflected.

In the opposite case, even if they are lightly deflected, they move out of the floor beams. One of them pushes on the wheel-arch which, if the impact is very serious, can break in two parts; then the wheel introduces into the car compartment. The feet are often near the wheel-arch. Moreover, the wheel-arch's deformation produces the floor's deformation because they are butt-welded together. At the end, the wheel-arches are mainly made with two sheet-metal pieces butt-welded together under a horizontal direction, so they can easily move out under the compressive force of the wheels.

The rear occupants present less frequently feet injuries.

Usually, these injuries occurred when the rear occupant moving forward, kept his feet squeezed under the front seats. We can notice fractures of ankle-bones or of the part situated just upon. These injuries are due to direct impact; they are not frequent in our cases.

THE ENGINE DISPOSITION INFLUENCE

We noticed that the engine disposition has an important influence on the frequency of the inferior members traumas.

- in the rear engine cars, in frontal impact, the deformation arises very frequently, even if the crash speed is low, at the front floor part. A third of the kind of cars involved in frontal impacts produce feet injuries to the front occupants.
- for cars with engine placed forward, the latter seems to screen. If the engine is longitudinally placed, it protects in the case of taking part in the crash. Now, in 40% of frontal impact accidents less than a third of the forward part is concerned.

In the vehicle with longitudinal frontal engines, which are very numerous, we can find about 10% of vehicles whose front passengers have suffered from feet injuries during frontal impact.

But, if the engine is transversal it works as a screen in the most part of frontal impacts; just 4% of these cars produced feet injuries to their occupants during frontal impacts.

POSTURE'S IMPORTANCE

Apparently the occupants' posture intervenes in the occurrence of the inferior members injuries. In the vehicles where the seat is straight and high, the driver sits up strictly, his leg making an almost straight angle with the thigh; for the latter no feet injuries have been remarked. For example, no occupant of the Renault R.4 investigated showed any such wound.

CONCLUSION

Medico-Legal Aspect

The tibio-tarsal articulation particularly fitted demands an exact reconstitution to avoid functional problems. It constitutes, as well as the foot an area exposed due to the lack of muscular or fat protection and the fractures and dislocations of this region are mainly open injuries, which always leads to a risk of infection particularly dangerous on an articulation.

The medico-legal examination of these traumas is always most careful: we are studying a person who has been in hospital for some time and was reeducated in a specialized center and whose articulation has not entirely recovered.

We must point out that these anatomical troubles tend to become more serious during the years and this injury if not being a vital factor, can cause invalidity for life.

Some Considerations on the Development of Safety Devices

The study carried out on safety problems tends to protect the head, chest and knees; it does not seem that presently any research is leading on inferior members protection.

In regard to the problem of the pedals, it could be interesting to study the distribution of forces in terms of the surface of the pedal.

For the floor deformation, it would be interesting to conduct frontal impact tests concerning only a third of the front part of the vehicle (test on a corner of a barrier). For the introduction of the wheels, crash tests would be conducted with deflected wheels during the impact.

EXPERIMENTAL SAFETY SUBSYSTEM CITROEN PROGRAM

MR. MAURICE CLAVEL, *General Delegate*

Anonymous Society of Citroen Automobiles

For nearly eight months the Research and Development Department of the Citroen Automobile Company has been carrying out studies and experiments that meet with the requirements of the program set up by the French Government, known as the Action Thematique Programme Securite Secondaire, or in English, Experimental Safety Sub-System (ESSS), the goal of which is the same as the ESV-NATO CCMS program's, the only difference being its approach.

Mr Bohers, responsible for coordinating the Programs and Rules in the field of safety of our Research and Development Department, is going to put forth the synthesis and the broad lines of action of our work. It is a sort of Progress Report that, moreover, he will situate for you within the framework of the general French Experimental Safety Sub-System Program. This short talk will be followed up by a film illustrating the work carried out in connection with the first stage of our studies and experiments. Documentation developing the technical themes touched upon in this film will be given to each National Delegation attending the Conference.

I would like to remind you that within the framework of the French program Citroen chose as early as 1971 the small 1500-pound dry-weight vehicle as its study basis. In doing this, although backed up by a long tradition and vast technical achievements characteristic of our company, Citroen has not lost sight of the fact that it is tackling not only the most difficult problems but the most important and pressing ones that must be solved. Small and medium-sized European type vehicles are the most seriously threatened by the projects of requirements of the American Federal Administration in that these very cars are practically the only instruments of motorization of the least-favored socio-professional categories in France as well as in the other industrialized countries of Europe.

Since the Second International Conference NATO/CCMS on Experimental Safety Vehicles held in Stuttgart, two new elements have arisen concerning the United States Government's official attitude which tends to encourage and strengthen our determination to accomplish the arduous task we have taken upon ourselves.

Firstly, the publication of the RECAT report emanating from the White House itself exposes the legitimate concern of the United States Government in the realm of cost/efficiency and cost/acceptability for the nation, in the case where the requirement projects set up by the Federal Administration would be put into force in the not-too-distant future. The conclusions of this Report take on quite a different dimension to our European eyes in that the application of the American Safety regulations foreseen for 1976 would bring on almost a 30% increase of the present price of 1800 dollars, a figure which the small vehicle chosen by Citroen costs and it remains to be seen if all these regulations could technically be applied.

This report confirms thus the soundness of the demanding but realistic approach of the French Experimental Safety Sub-System Program that enables us to study fundamentally the safety problems related to the still poorly known mechanics of impacts and collisions by groups of sub-systems and partial structures in order to attain coherent and economically acceptable solutions for the consumer and the nation.

Moreover we felt a great satisfaction in the very recent statement of the Secretary of Transportation, Mr. John Volpe at an official reception for three of the American Experimental Safety Vehicles in Washington on March 20.

Mr. Volpe publicly stated, and I quote him in English so as not to betray his thoughts: "We will be striving, as the program continues, to assure that safety features are available at a price people can afford to pay." This statement also confirms the soundness of our action which consists of increasing the secondary safety qualities of the small vehicle at the bottom of the European range by submitting it to realistic tests based on accident statistics and by finding for it adapted technical solutions while conserving its tested qualities of Primary Safety (road-holding, maneuverability, braking, visibility). Mr. Volpe's statement encourages us to pursue our fundamental approach to a problem, the solution of which will not in any way have to distort the very function of the small vehicle, by adopting technologies that the 4000-pound ESV's illustrate and that would succeed in increasing the weight, power and therefore the cost of the vehicle. Thus putting it out of the reach of the socio-professional strata of the population for which this small vehicle is, moreover, designed.

To conclude, whether it be RECAT report or Mr. Volpe's statement, we note that the work carried out by our company within the French ESSS program today corresponds to the official American point of view by acknowledging the legitimacy of mass motorization, in other words, the fundamental right and possibility for each individual to acquire an automobile that is both safe and economically acceptable. The American position thus officially gives the right to exist to these small functional European cars that are the specific object of our study and our ESSS Experiments, that pollute cities less, are less aggressive in collisions involving other vehicles or pedestrians, less cumbersome for parking, more evolutive and maneuverable, less involved in corporal accidents than heavier cars as have proved statistics established in France by the National Organization for Road Safety (ONSER) and whose cost is geared and must remain geared to medium and low incomes.

Need I remind you that these universally acknowledged characteristics take on a special importance at a time when they will, from now on, be expressed in terms of ecological and social guidelines that, since the conference held in Venice last April under the auspices of the European Economic Community, have progressively been introduced into the study of qualitative finalities of industrial development, a new and fundamental concern of our governments.

I shall leave this to your reflection, and I call upon Mr. Bohers who is going to situate for you, through films, the first stage of our work within the framework of the French ESSS program and expose the conclusions we have drawn from it.

CITROEN PROGRAMS AND PROGRESS REPORT

MR. SERGE BOHERS, *Coordinator of Automotive Standards and Applicances*

Anonymous Society of Citroen Automobiles

INTRODUCTION

Our company's Progress Report which is being presented deals essentially with the preliminary stage of the work we regard as vital to the preparation of and advancement toward the goal proposed by Programmed Thematic Action, initiated by the French Government through the Transportation Research Institute (Experimental Safety Sub-System ESSS).

The film we are going to show you illustrates the different phases of this preliminary stage.

Our work and our realizations concern a vehicle in the economy class whose weight range (without load) corresponds to *a mass of about 750 kg (1,500 pounds).*

This is a goal for which no effort has been spared. The experience our company has acquired over many years for this category of vehicle will ensure our success.

The topics we touch upon in the preliminary phase of the work concern in particular:

- The improvement of the survival space in the case of frontal collision.

  The residual space, after collision, will have to become the "*survival space*" at frontal impact speeds against fixed barriers or other vehicles. These speeds are *greater than 48 km an hour and there are 2 or 3 anthropomorphic dummies inside.*

  We are also trying to limit the acceleration level inside the car to a no-injury level for the occupants *equipped with restraint devices.*

- The improvement of the survival space in the case of side collision.

  Here and especially in the case of the vehicle chosen that of a light-weight car of small dimensions the difficulty becomes even greater.

  As in the former case, we endeavor not only to limit the level of intrusion in the vehicle but to limit the stresses exerted on the occupants equipped with restraint devices to no-injury levels as well.

  We are thinking of diminishing the aggressiveness on the vehicles' front section. This is a principle we have applied to our latest commercialized vehicles such as the GS and SM models by adopting rounded bumpers, slanting hoods and very slanted windshields.

  The combination of these three features gives us a front form which is as least aggressive as possible to the pedestrian as well as to the vehicle that is hit.

OUR ACTION IS SITUATED IN THE FOLLOWING FRAMEWORK:

The very fact that the ESV program was divided into two categories in the U.S. vehicles of 4,000 pounds and those of 2,000 pounds *shows how different the problems of safety from the top to the bottom of the vehicle range are.*

Our experience with small cars at the bottom of the European range showed us in the past *how difficult it could be and, many times impossible in the lower European range to apply one solution to all vehicles whatever the mass* without sacrificing the fundamental specifications by making the vehicle an unwieldy one with a price that would put it out of the reach of the market it was designed for, as Mr. Clavel pointed out.

This type of vehicle which is economical and functional and answers a growing demand is the result of economically acceptable technological solutions.

PERFORMANCES COUNTED UPON IN THE FINAL STAGE OF THE PRELIMINARY PHASE

- *Frontal collision* improves the survival space

  Our criteria are geometrical (survival space) and biomechanical (limitation on the stresses exerted on the vehicle's occupants). It seems fitting in this respect to underline the need to perfect the anthropomorphic dummies in order to obtain a better reproducibility of the measures carried out.

We are trying to get a maximum amount of safety performance while keeping to a minimum the unwieldiness of a vehicle that must be part of the most popular range vehicles.

- *Side collision*

  As in the case of frontal collision, our criteria are geometrical and bio-mechanical ones. Their ultimate values are to be set down in function with the conditions decided upon for side collision.

  We are trying to get a maximum amount of safety performance while keeping any unwieldiness down to a minimum on the vehicle and while *guaranteeing an acceptable homogeneity between the criteria of frontal collision and the criteria of side collision.*

  This absolute necessity limits the *aggressiveness level* by taking into account:

  the mass and speed of the vehicles considered.

  the application of a law of dynamic effort or a law of work (effort, displacement.)

  The notion of non-aggressiveness, or at least of limited aggressiveness, tends to increase the length which can be distorted and compressed of heavy vehicles.

WORK PROGRAM:

It comprises five main phases divided into three stages.

PRELIMINARY STAGE is the object of our progress report we are presenting today.

First Phase – *Research for a collision speed* linked to economically acceptable solutions. This research is carried out on existing vehicles in order to choose the best-adapted structure and to improve its performances.

Second Phase – *Analysis of the passengers' behavior* in function with the restraint device chosen and the frontal and side collisions considered so that the passenger decelerations recorded lead to the calculation of an acceptable "severity index."

This stage will enable us to point out the antagonism of some rules concerning primary safety and secondary safety. We can never insist too much on the following example: the ruling on the driver's field of vision may go against the qualities of resistance upon impact of a structure by imposing a diminution of the section and a position of the windshield pillars, thus condemning certain vehicle forms that give the driver and front-seat passenger greater longitudinal displacement possibilities.

Third Phase – *Definition of the structure while seeking partial structures able to dissipate energy.*

- Experimentation on partial structures such as: chassis, platform, bumpers, side-members, wheelhouse, etc.
- Experimentation upon the whole vehicle.

STUDY STAGE

Fourth Phase – *Study and execution of the structure defined* in the course of the third phase.

This realization will be tested:

- on the vertical bench
- on the catapult
- on the fixed barrier
- on the vehicle (side collision)

FINAL STAGE

Fifth Phase – *Approval of the project.*

Realization according to a summary study of several prototypes designed to undergo tests under conditions which have proved themselves to be the least favorable.

Our activity within Thematic Action *began in the fall of 1971.*

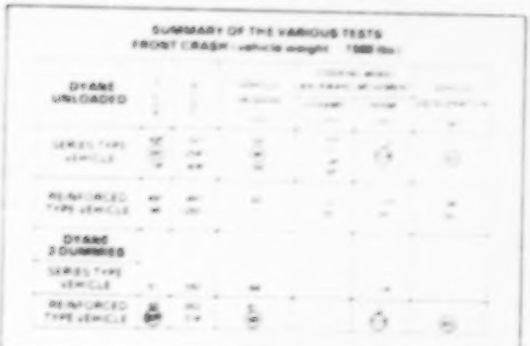
By the spring of 1972 we have answered the phases 1 and 3 of the Preliminary Stage and the second phase is now underway.

CONCLUSIONS WE HAVE DRAWN FROM THIS PRELIMINARY STAGE AS OF DATE

- It seems that *even for small vehicles* the collision standards concerning the structural elements, standards that are enforced today, were technologically within the reach of our knowledge of the conception of vehicles in this category, and this confirms, for the lower European range, certain conclusions of the RECAT report of February 28, 1971.

  That is what has to be said for the past.

As for the future, *it is imperative to take into account economically acceptable technological possibilities and the solid knowledge in the field of the mechanics of collision*, a field which still remains to be explored, especially for the small vehicle whose mass is less than 1,000 kg (2,000 pounds) and that was the subject of the second and third stages of our study within the framework of the French ESSS program.



SUMMARY OF THE VARIOUS TESTS
FRONT CRASH (vehicle weight 1500 lbs)
DYANE UNLOADED
SERIES TYPE VEHICLE
REINFORCED TYPE VEHICLE
DYANE 3 DUMMIES
SERIES TYPE VEHICLE
REINFORCED TYPE VEHICLE

FIGURE 1

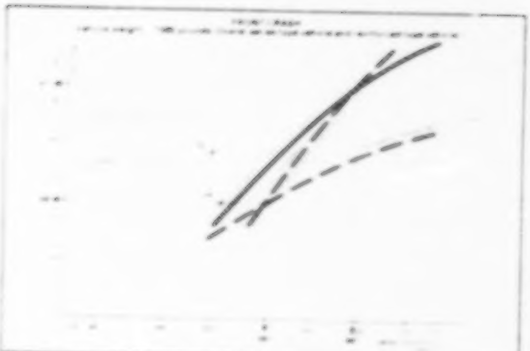


FIGURE 2

- Figure No. 1 and the crush curves in function with the speed, Figure No. 2
- without load
- with 3 anthropomorphic dummies inside show an impact speed during perpendicular collision against a fixed barrier with *3 dummies inside could hardly be greater than [illegible] km/h for the category of vehicle under consideration.*

The test during an *oblique collision of 30°* at a similar impact speed would only *make it harder to meet the requirements. The survival space* could be checked *without a load* at a perpendicular collision speed of *about 65 km/h.*

The use of the 3-anchored safety belt becomes obligatory and represents an undeniable source of safety.

AGGRESSIVENESS OF THE VEHICLE TOWARD PEDESTRIANS

A non-agressive design for the front section of the vehicle (slanting hood, rounded shape of the grille) together with an accentuated sloping of the windshields and the absorbing materials used, help diminish quite perceptibly aggressiveness toward pedestrians in urban traffic. The combination of these elements have been applied on our new type GS and SM vehicles.

The filmed sequence you will see will show you that an average-sized pedestrian is not projected towards the front but turns over onto the hood. Moreover, the point of contact between the pedestrian and the car occurs below the hip and region of the body where fractures are particularly serious.

FILMED DOCUMENT

The document we are presenting illustrates our progress report and comprises five parts.

FIRST PART — Research in laboratory for improvements that could be made on *partial structures* in order to increase their performance in *dissipating energy.*

SECOND PART — Application of these improvements on a 1,500 pound vehicle without a load like the *DYANE* model.

Research for a means of increasing the performance during frontal collision using a reinforced mass produced vehicle.

THIRD PART — Performance of the DS and SM models during frontal collision with a full load at a speed of 48 to 50 km/h.

FOURTH PART — Frontal collision between a GS and a pedestrian.

FIFTH PART — Side collision at a 90° angle.

FIRST PART

FILMED DOCUMENT
THE WORK IN OUR RESEARCH LABORATORY

VERTICAL BENCH

The need for improvement of the structures before difficult and costly overall tests on the testing ground was the factor that made the Testing Laboratory of the Framework Department create a working tool.

We had to simulate collision tests against a fixed barrier to be applied to sub-assemblies and partial structures.

The element to be tested is affixed to a cart that rolls vertically along 2 beams. This enables an element to be dropped from about 11 m onto a concrete block with an impact speed that can attain about 45 km/hr.

For kinetic energies beyond the possibilities of this bench we use the method of successive impacts of L LOCATI.

This procedure enables us to exploit the shortening in function of the time of a structure or of a part of a structure corresponding with its deceleration.

Usual inverse procedure: a structure undergoing tests is affixed to the block and hit by a mass with an accelerometer falling vertically, thus enabling us to measure:

the equilibrium at the center of gravity of the mass

$$M\gamma = F_A - P$$

or $P = Mg$

F_A = reaction of tested object

gives us $F_A = M\gamma + P$

This procedure allows us to exploit:

Evolution in function with the time

acceleration $\gamma = f(t)$

stress $F_A = M\gamma(t) + P$

speed $V_t = V_0 - \Sigma_0^t \gamma(t)\Delta t$

crush $X_t = \Sigma_0^t V(t)\Delta t$

energy absorbed by the tested object

$$E = WA \text{ (Work of } F_A\text{)}$$

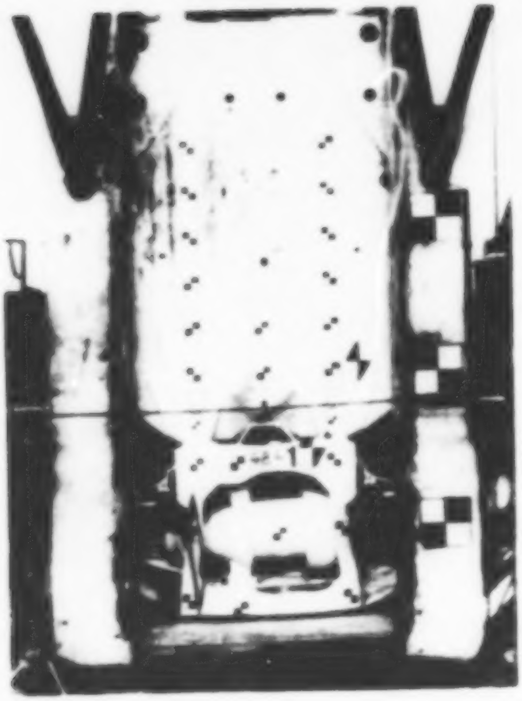
Variation of FA in function with the crush

$$F_A = f(x)$$

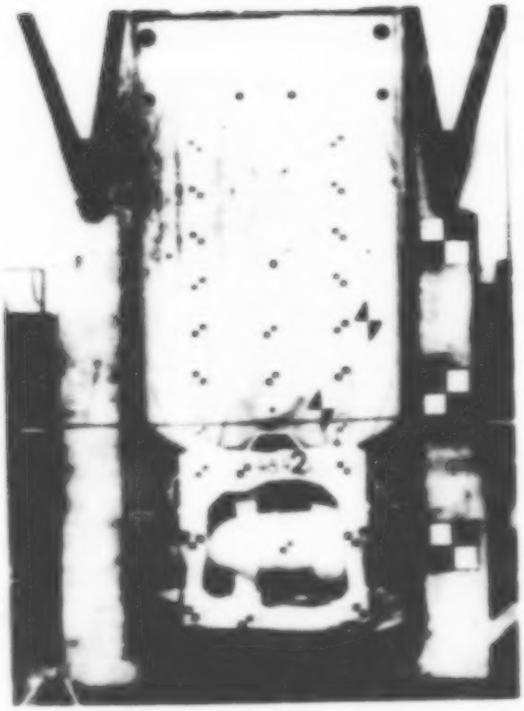
TEST NO. 484 SIMULATION OF FRONTAL COLLISION ANALYSIS OF DISTORTIONS ON GS SEDAN

We analyze, in two successive impacts, *the behavior of the vehicle's base structure.*

First impact (test no. 484-1)
corresponding to an impact speed of
34.4 km/hr

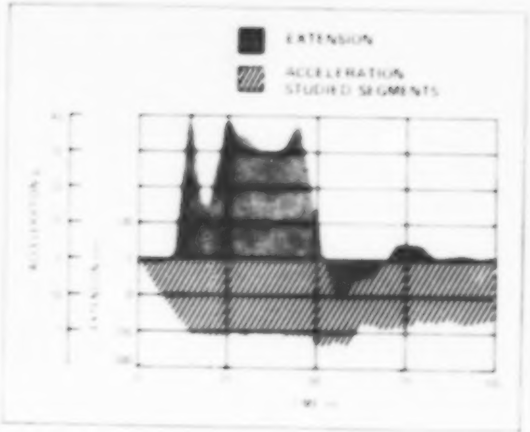


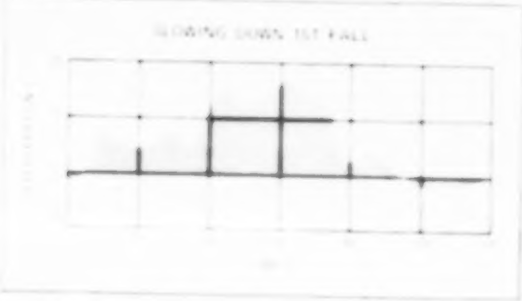
Second impact (test no. 484-2)
which together with the first impact corresponds to an impact speed of
48 km/hr

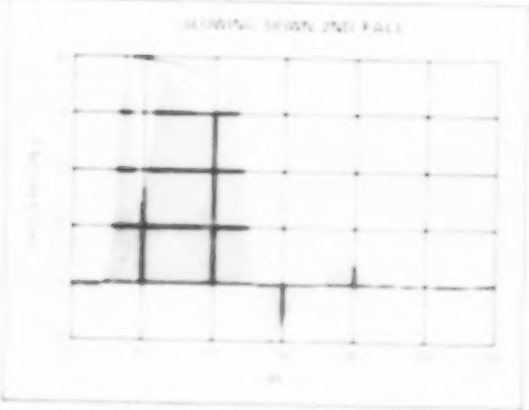


The degree of distortions is measured, after each impact, with the help of the segments marked 1 to 10 that are integral parts of the structure.

The elements recorded during the 2nd impact determine the curve of *shortening in function with the time of segment 1-2 in connection with the deceleration of the passenger compartment*.







This type of curve enables us to define *a hierarchy of distortions* and thus allows us to action the *various structural portions in a set order*.

TEST NO. 449-1

ENERGY ABSORBERS
DYNAMIC TESTS

Within the framework of the general study of safety problems, we are *carrying out on the vertical bench tests on portions of structures dissipating the energy*.

We show you a portion of a conical-shaped structure during a test.

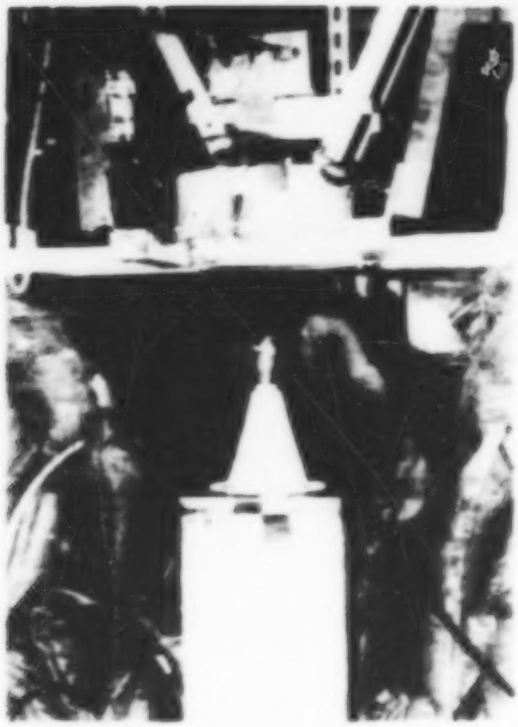
This form was chosen for (i) simplicity of application and (ii) reproducibility for our theoretical research.

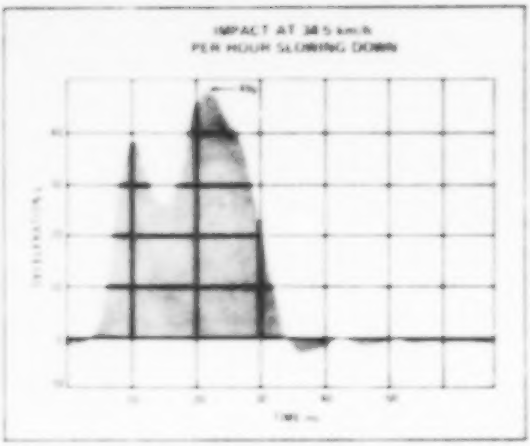
Two (standard) procedures were chosen:

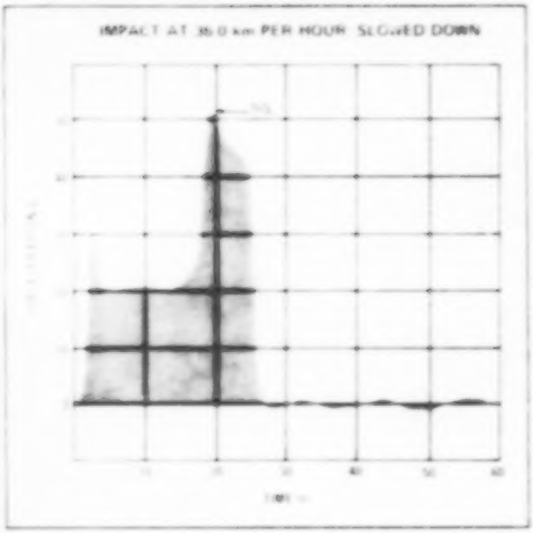
- fall of a loaded trolley at an impact speed of 14.3 km/h
- fall of a free mass at an impact speed of 36 km/h

The curves corresponding to these tests represent the deceleration in g of the mass in function with the time.

The deceleration represented by the first rising part of the curve is perceptibly constant, hence the *reproducibility of the system*.





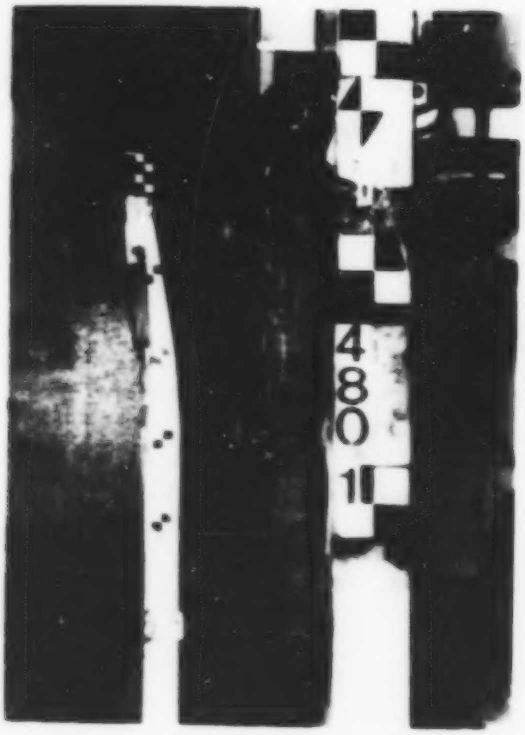


TEST NO 480-1/3 **CHASSIS OF THE DYANE**
INFLUENCE OF THE ABSORBER
FALL OF A MASS OF 500 Kg
IMPACT SPEED = 21.2 km/hr

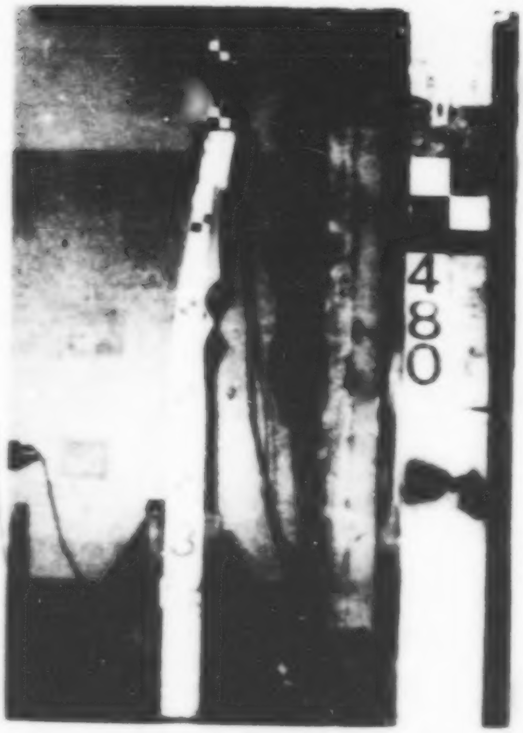
We are seeking to distribute the distortions on a large structural portion:

- in mass-production vehicle (test no. 480-1)
- in a vehicle equipped with an absorber on its frontal section (test no. 480-3)

The sequences presented show the behavioral difference of the chassis in both cases.


480
10

480
13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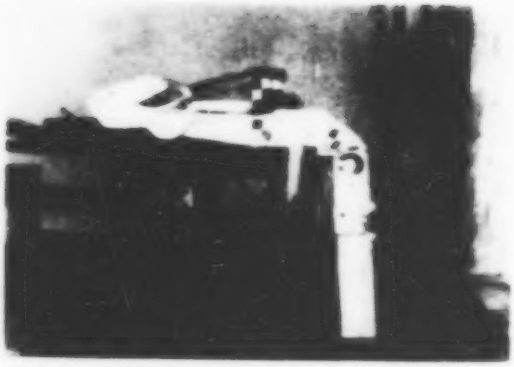
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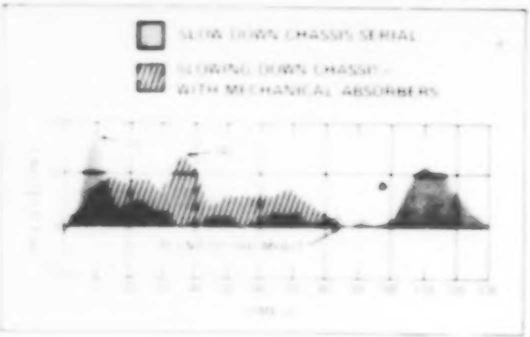

▢ SLOW DOWN CHASSIS SERIAL
▨ SLOWING DOWN CHASSIS – WITH MECHANICAL ABSORBERS

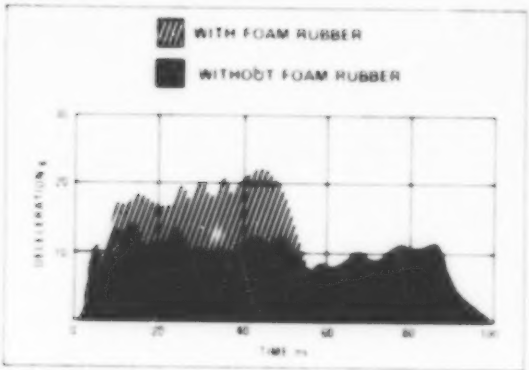
The curves underline the very clear influence of the absorbers

- the diminution of the duration of distortion
- no discontinuity of rigidity

TEST NO. 565.2.2 ENERGY ABSORBERS RIGID POLYURETHANE FOAM DYNAMIC TESTS

Another solution to the problem of energy dissipation has been studied.

The addition of rigid polyurethane foam to a hollow structural portion made of a relatively thin sheetmetal (thickness less than 1 m/m) yields a very good energy absorber.



The curve represented shows the dissipation potential of a hollow part (thickness of sheetmetal 8/10) padded with foam having a density equal to 90 gr per liter.

Temperature tests (heat-cold) are underway to confirm this.

TESTS NO. 488.7/10/17 CHASSIS OF THE DYANE INFLUENCE OF BOTH TYPES OF ABSORBERS FALL OF A 500 kg MASS IMPACT SPEED = 28.2 km/hr

The tests we are presenting illustrate the increase of energy dissipation offered by both types of absorbers on a portion of the platform of a DYANE.

- Mass-produced chassis
- Addition of rigid polyurethane foam in the hollows forming the platform's side members and in the central part forming the floor
- Addition of an absorber onto the frontal section

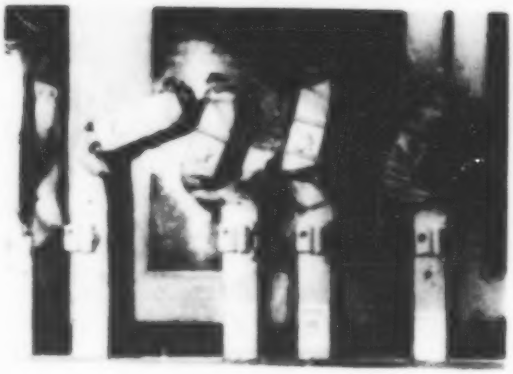
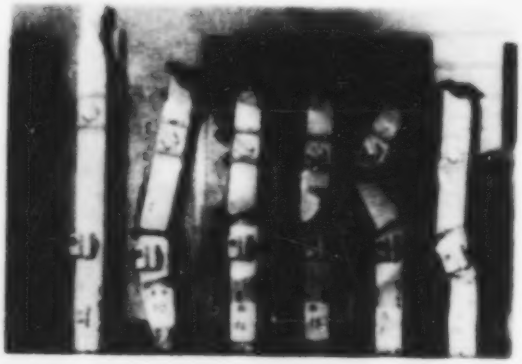
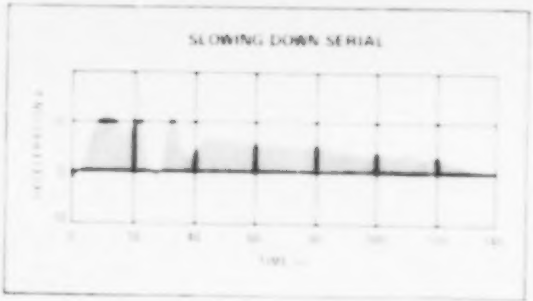
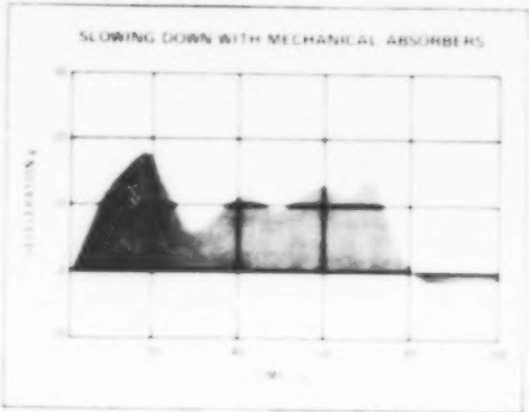


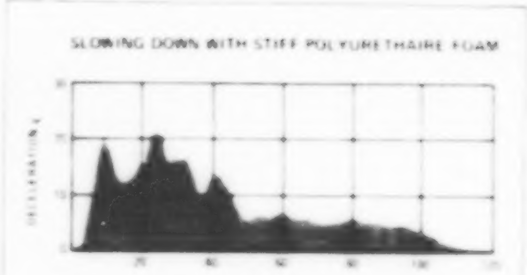
TABLE A

TEST RESULTS WITH RIGID FOAM COMPARED TO THE MASS PRODUCTION AND A "MECHANICAL" REINFORCEMENT				
	Test No	Crush	Average crush	Photo No
Platform Mass Production	7 8 9	325 281 332	312	1 and 2
Platform Reinforced	12	353	353	1 and 2
Platform with Foam in A	14 15	235 252	243	1 and 3
Platform with Foam in B	13 16	246 236	241	1 and 3
Platform with Foam in A and B	10	227	227	1 and 3









CONCLUSIONS

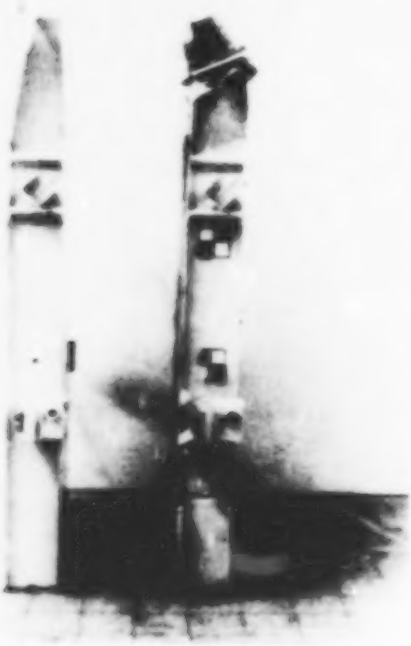
An examination of the crush figures shows there is little difference among the three possibilities of filling certain regions with the foam.

Diminution of crush in comparison with the mass production:

about 20% for the foam in **A** or in **B**

about 25% for the foam in **A B**

The reinforced part (test no. 12) is crushed more than those of the mass production.



An examination of the photo above shows that:

The foam in **A** and **B** enables a practical elimination of distortions within the region situated between the front axle fittings and the rear fitting of the suspension unit.

The distortions occur behind the front fitting of the suspension unit (N.B. that on a car the suspension may brace this region).

The foam in **A** does not allow us to choose the area of distortion (in front of or behind the foam), hence a marked dispersion in the aspect of the distortions.

The foam in **B** gives an even distortion in front of the suspension fitting.

The decelerations recorded of the pendulum show in the tests with foam a more continuous resistance *quality and a shorter total crush duration than in the tests without foam.*

A comparison of the deceleration curves shows the energy dissipation possibilities of both solutions. We note, between 0 and 40 ms, a greater energy dissipation in the foamed solution which, on the other hand, presents a crest of 20 g at 10 ms.

TEST NO. 524.13 BUMPER SAMPLES DYNAMIC TESTS

The exterior protection of the vehicle against small impacts (US 215 and ISO) makes it necessary to consider using products or materials capable of dissipating energy.

We are studying in connection with PBU the application of semi-rigid foams that might help solve the problems laid down.

We are testing parallelepiped section — 60 cm in length, 15 cm in width and 8 to 12 cm in height.

The tests should allow us to estimate:

the absorption capacity in function with:

- the form of impact device
- the surface of contact and the volume of foam
- the quantity of energy introduced

the maintenance of performances in a series of impacts;

the amount of stresses the structure to receive these parts will have to undergo.

For the bumpers of the small vehicle having to tolerate an impact speed = 8 km/hr or 2.22 m/s, the energy introduced,

$$E = \frac{1}{2} \times 800 \times \frac{2}{2.22} = 1972 \text{ joules}$$

TEST NO. 527 PENDULUM TEST OF BUMPER ABSORBERS ON THE FRONT SECTION OF THE VEHICLE

The pendulum is a mass of about 800 to 1400 kg suspended from a parallelogram:

length of the arm = 3.500 m
distance between the arms = 0.400 m
eccentricity of the arms = 0.080 m

Its profile is conform with ISO and US 215 standards.

The cart has a total mass from 800 kg up, was executed in sections, is equipped with two rigid axles fitted with wheels, pneumatics with variable wheelbase and is designed to be fitted with bumpers.

The tests allow us to measure:

The *impact speed* as function of the height of the fall of the pendulum:

$$v_{11} = \sqrt{2\,gh}$$

The *accelerations*, with the help of SETRA capacitive accelometers with air absorbers.

The *stresses*, deduced from the accelerations.

SECOND PART

FILMED DOCUMENT

TYPE DYANE

PERPENDICULAR FRONTAL IMPACT

v = 49.8 km/hr

DRY WEIGHT

Vehicle at the bottom of the range in European standards characterized by:

a platform or chassis architecture

a length greater than that of the recent vehicles of the same category (L = 3.870 m)

The great percentage of energy absorbed by the lower part of the vehicle (below the center of gravity) results in:

a very slight backward movement of the steering column

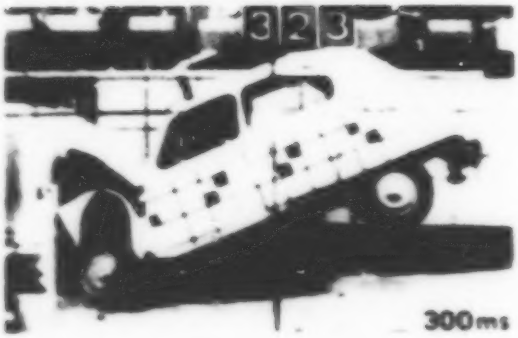
quite an acceptable amount of survival space

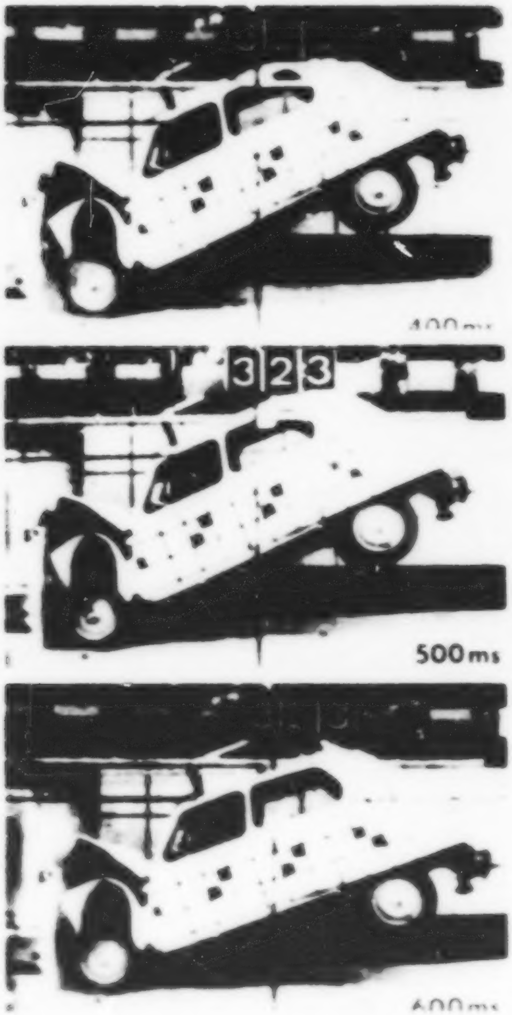
a lifting up of the rear section of the car

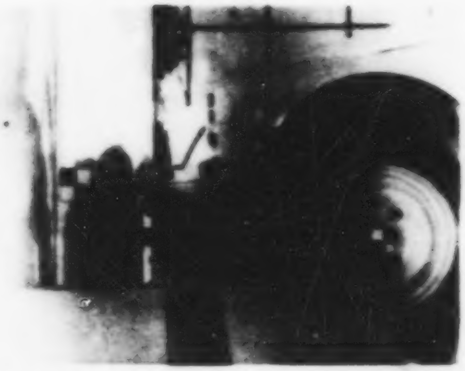
(maximum at t + 400 ms)

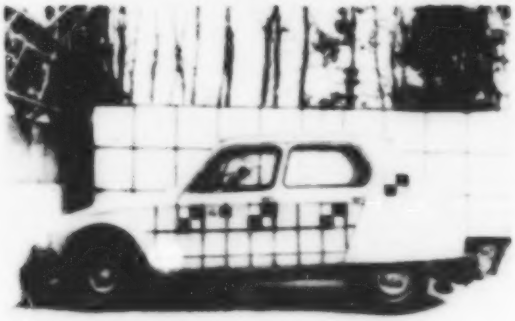
The lifting movement which begins after the upward movement following the impact against a fixed barrier can even result in complete overturn in the case of an impact against a fixed barrier at a greater speed.

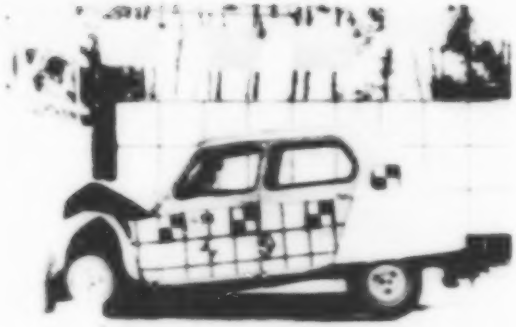
It is vital to compare the "attitude" of the vehicle during a simulation of a real accident.

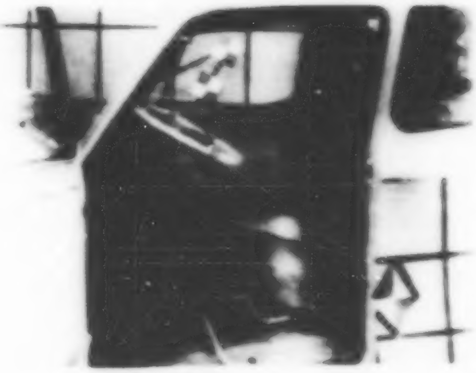












DYANE

TEST NO. 491

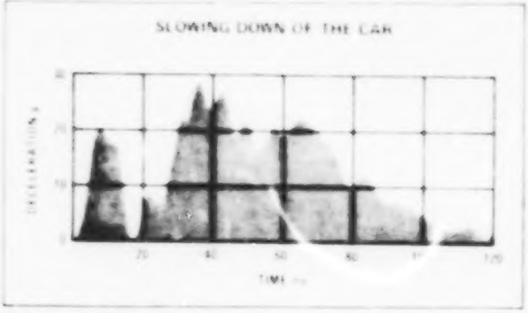
PERPENDICULAR FRONTAL IMPACT
v = 49.2 km/hr
ADDITION OF ABSORBERS

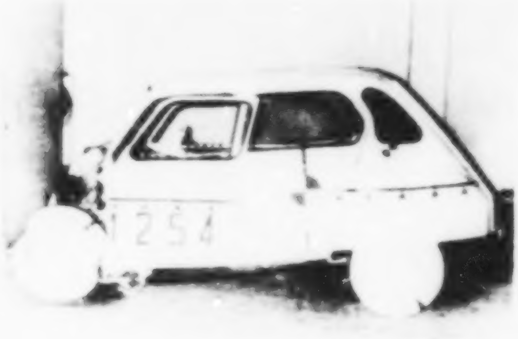
The phase of research for principles in the Research Laboratory is put in concrete form on a vehicle tested on the testing ground.

We carry out an overall test on a vehicle whose platform is equipped with an energy absorber on its front section.

The deceleration curve of the car shows between 0 and 20 ms a greater increase of the dissipation of energy.

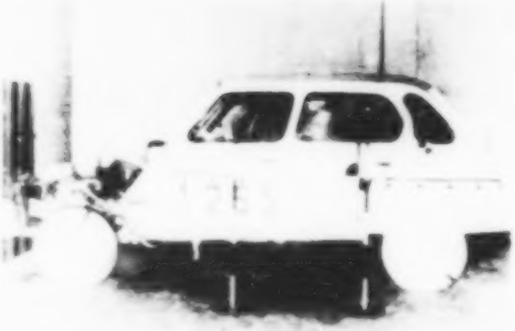
The behaviour of the vehicle and its survival space are greatly improved.





DYANE

TEST NO 1254/C **PERPENDICULAR**
1255/C **FRONTAL IMPACT**
v = 66 km/hr
TEST, DRY WEIGHT, ON CATAPULT



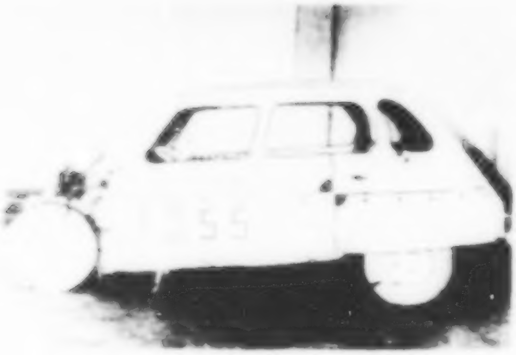
We compare at similar impact speeds two DYANE vehicles:

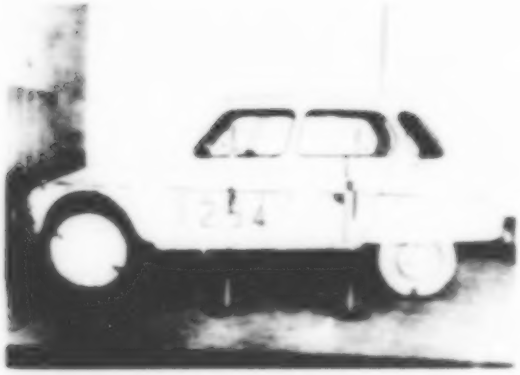
a mass produced vehicle

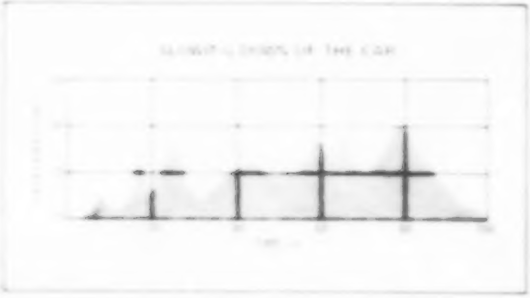
a vehicle with energy *absorbers*.

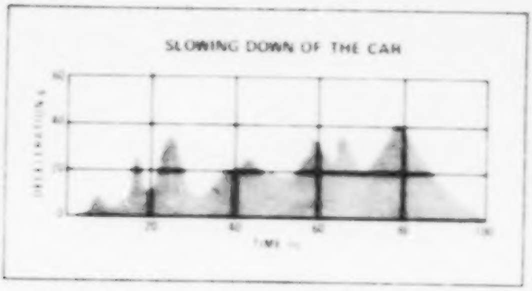
The vehicle with absorbers *marks a plain improvement in survival space after the impact.*

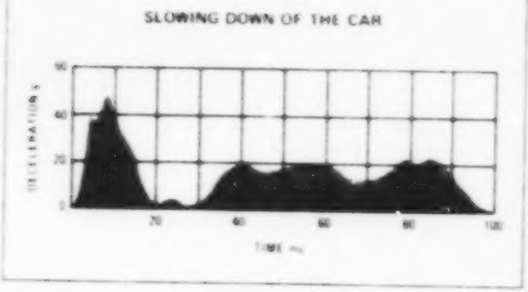
	Mass produced vehicle	Modified vehicle
crush of the vehicle in cm	96	77
maximum incidence of the vehicle upward (lifting of the rear)	60	45
maximum deceleration of the vehicle	40g	50g
backward movement of steering column in cm		
• dynamic	17.2	2.3
• permanent	11.5	0.3











DYANE

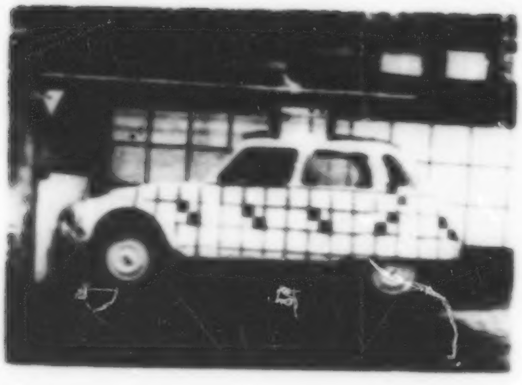
TEST NO. 406

PERPENDICULAR
FRONTAL IMPACT
v = 73.6 km/hr
DRY-WEIGHT

This test illustrates the remark concerning test 223 insofar as the amount of lifting of the rear of the vehicle is concerned in the case of collision against a barrier at a speed greater than 40 km/hr.

The locks on the car tested are not anti-burst.

Despite the extreme severity of the test, *the survival space still remains acceptable.*



DYANE

TEST NO. 518

PERPENDICULAR
FRONTAL IMPACT
v = 65.5 km/hr
THREE DUMMIES INSIDE

The test shown is so severe *for this category of vehicle* that we cannot technologically consider *the eventual requirement insofar as secondary safety is concerned.*

The chassis of the vehicle has undergone the following modifications:

- addition of polyurethane foam
- addition of mechanical absorbers in the front

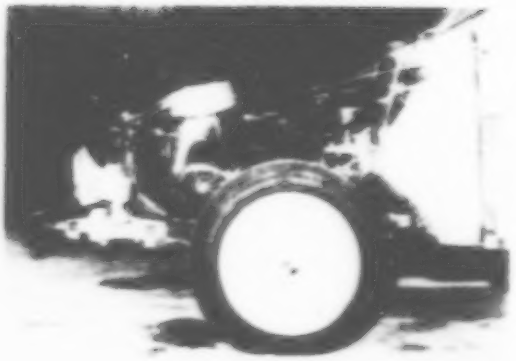
The hood, the front fenders and the wheelhouses have deliberately been eliminated (they seldom play a role in this type of accident) in order to analyze closely in the film the movement of the power plant.

Three anthropomorphic dummies are held in place by *reinforced* three-anchor safety belts.

By the end of the test the vehicle is at a 90° angle leaning against the fixed barrier at its rear section.

This "attitude" remains to be confirmed during simulation of a real impact between two cars.

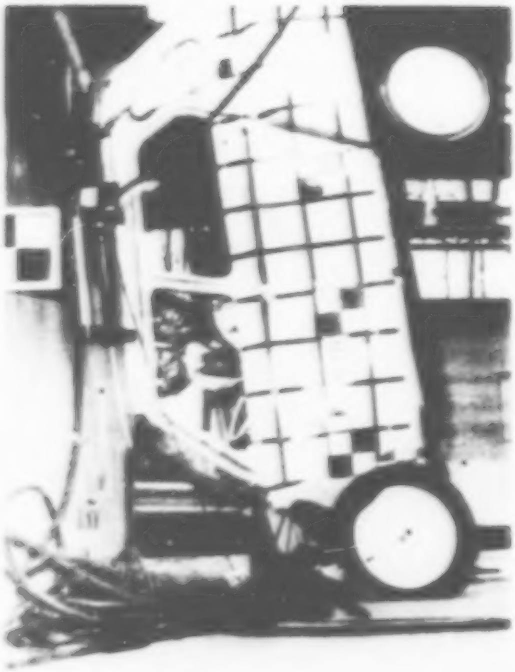
The maximum amount of deceleration at the level of the vehicle at 9 ms of t_0 = 49 g.

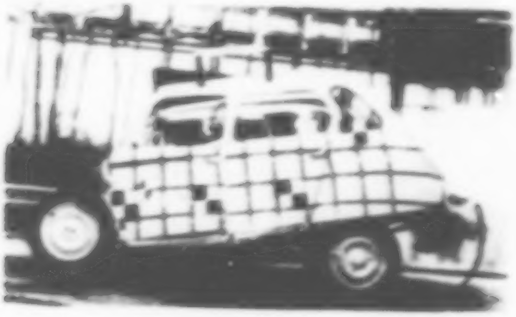


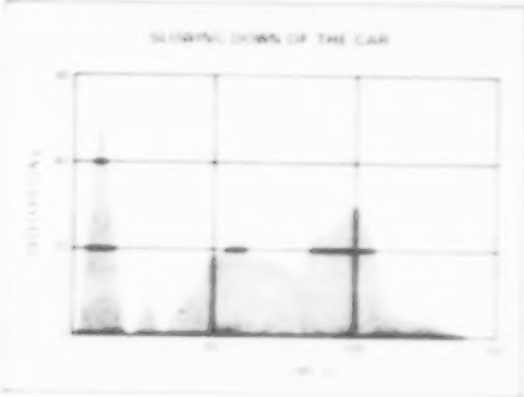
The vertical acceleration occuring in the front-seat passenger's head shows a crest at 100 ms of t_0 (end of impact) = 92 g during 6 ms.

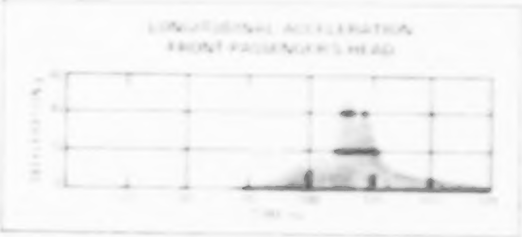
We have calculated the following severity indices:

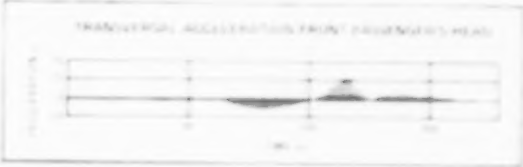
head of driver	1218
head of the front-seat passenger	1195
head of the back-seat passenger	787

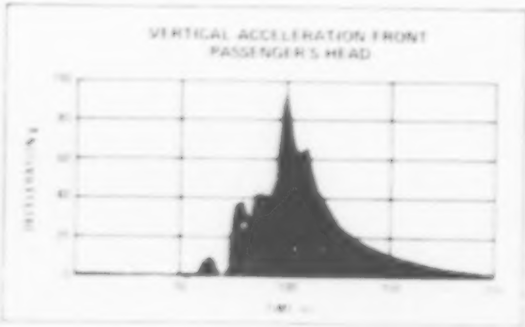


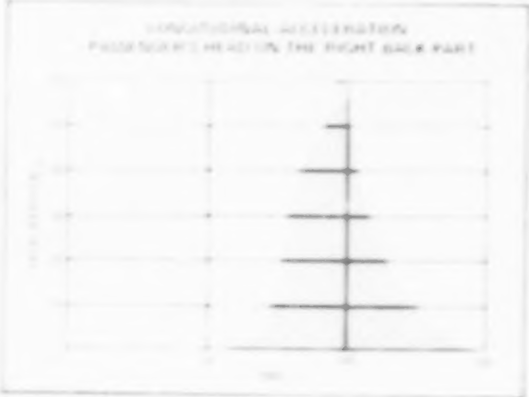


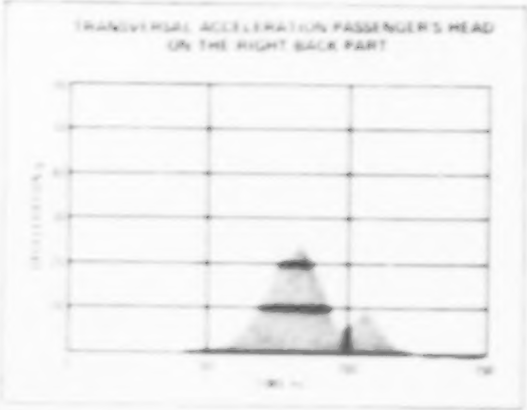


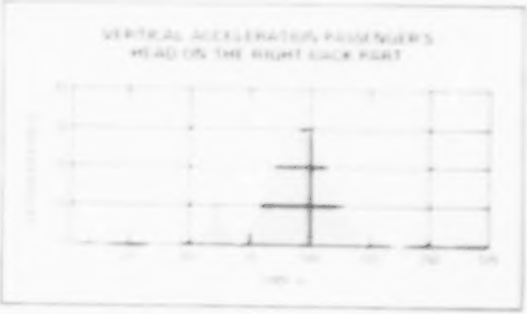












FRONT COLLISION – CAR AGAINST CAR

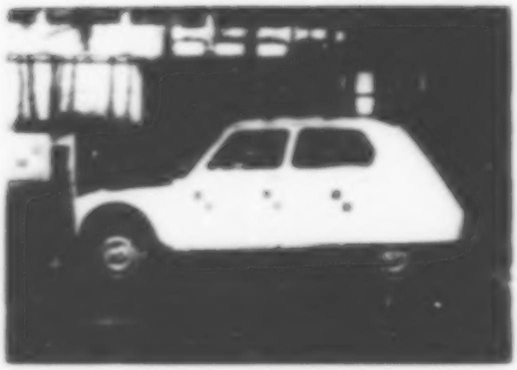
V ranges between 50 and 55 km/hr

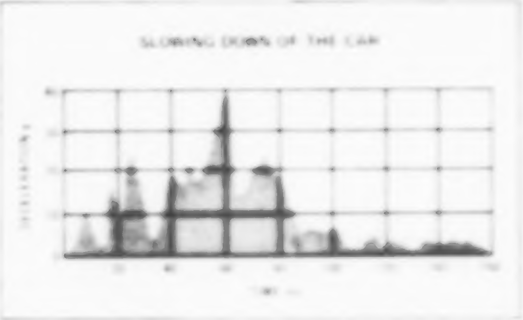
During this test, the attitude of the vehicles is perceptibly different from that noted in frontal perpendicular collision against a fixed barrier at comparable speed.

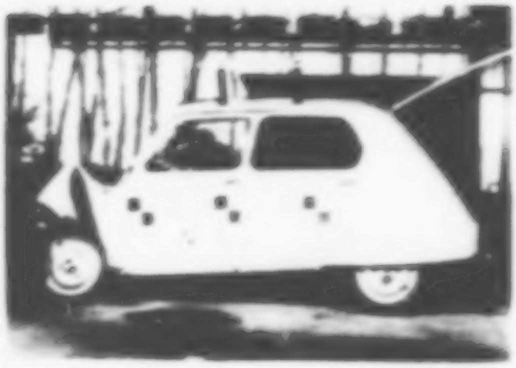
The lifting up of the rear section is lower.

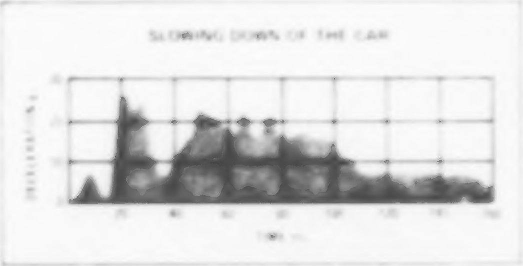
The test of frontal perpendicular collision against a fixed barrier may, in some cases, at the sight of the vehicle's attitude, distort the meaning of the conclusions by tending to condemn a type of structure and architecture of the vehicle.

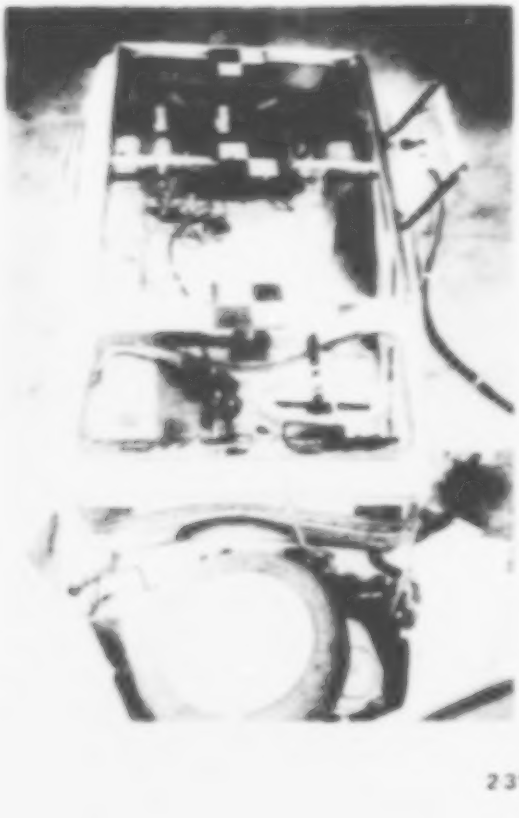
It seems necessary to multiply this type of very costly test, including the test of displaced frontal collision, in order to define the test of approval, the representative nature of which will be as broad as possible.











DYANE

TEST No. 517

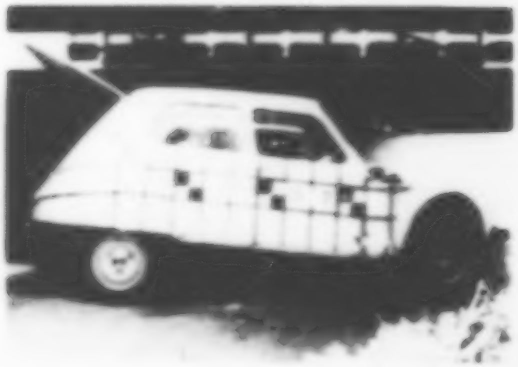
FRONTAL IMPACT AT AN OBLIQUE ANGLE OF 30°

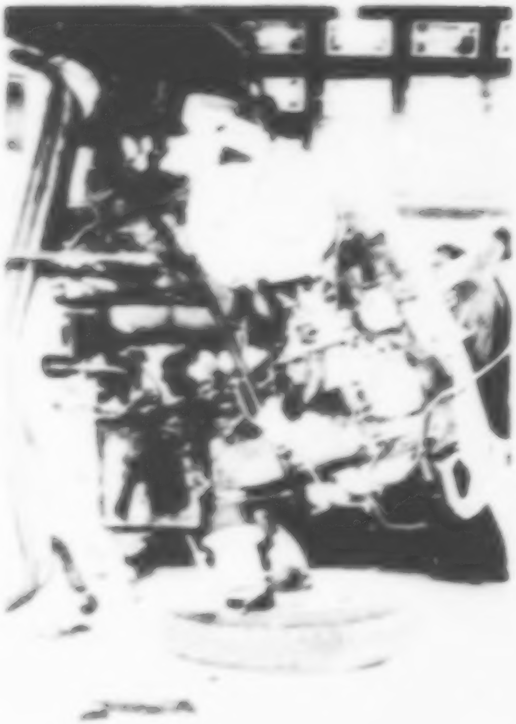
v = 50 km/hr

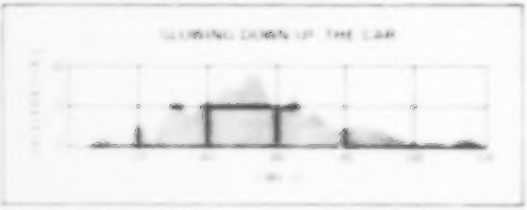
The character deemed the most representative of the test shown makes considerably more severe the consequences of the impact of the structure.

We note a crush on the vehicle's left side = 77 cm whereas in perpendicular frontal impact we note a crush on the vehicle's front section = 50 cm.

This type of test represents — at equal impact speed — a great severity in comparison with the perpendicular test and this lets us make progress in the field of secondary safety.







THIRD PART

FILMED DOCUMENT

DS SEDAN 48-50 km/hr
SM COUPE Full load

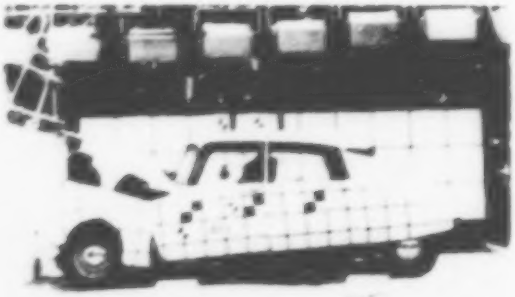
DS SEDAN

TEST NO. 481

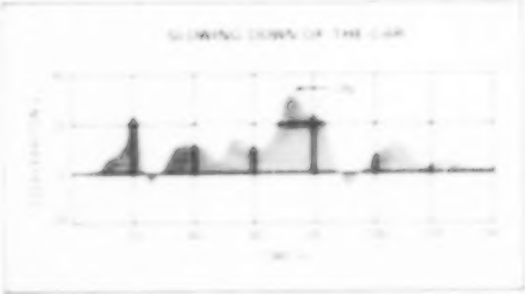
PERPENDICULAR
FRONTAL IMPACT
Full load v = 49.4 km/hr
Two Dummies in the front seat
3 anchor safety belts

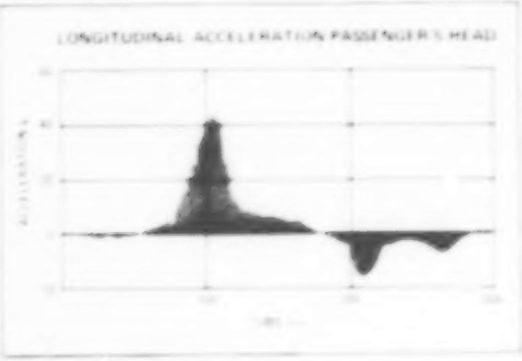
Another type of vehicle from our mass production is tested to check if it meets with Standard 208.

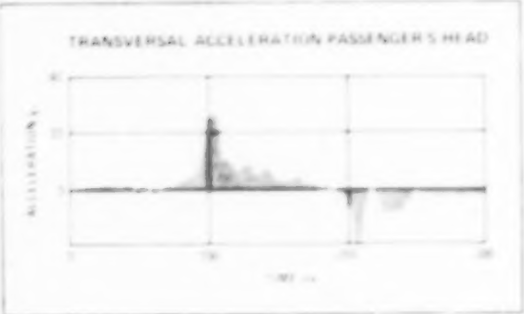
We note the influence of the architecture on the vehicle's behavior during standard test against a fixed barrier.

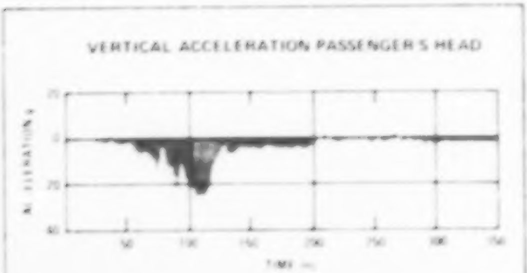


The attitude of the "DS" vehicle is different from that of the **DYANE** in that the rear section rises much less.









The deceleration curve of the vehicle shows at 20 ms of to a crest of 25 g that limits the dissipation of energy at the beginning of the impact.

This unfavorable reaction from the structure is compensated for by a possibility of distortion in the front section of the vehicle diminishing the dummy's kinetic energy.

The category of vehicle offering a distorting length in the front is more favorable.

The accelerations – vertically, longitudinally and transversally – within the anthropomorphic dummy's head on the passenger side give, after exponential ponderation in accordance with **GADD C.W.**, a "severity index":

$$I = \int_{t_0}^{t_1} \gamma^{n} \, dt = 526 \quad (1\,000)$$

γ = acceleration during the impact in g (resultant of the components of the acceleration within the head)

t = time in seconds (length of the impact) where 1 ms < t < 50 ms

n = 2.5 for the head, value deduced in accordance with the curve of **WAYNE STATE UNIVERSITY**.

SM COUPE

TEST NO. 478

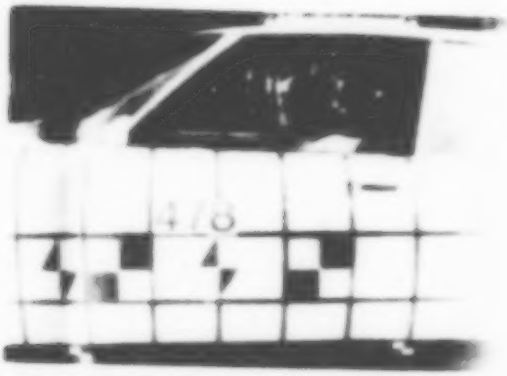
PERPENDICULAR
FRONTAL IMPACT
Full load v = 48.5 km/hr
Two Dummies in front seat
3-anchor safety belt

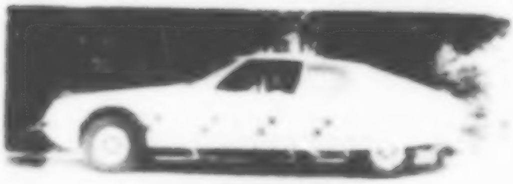
The deceleration curve of the vehicle shows, in comparison with the DS sedan, a greater energy dissipation at the beginning of the impact, the crest being 28 g at 50 ms.

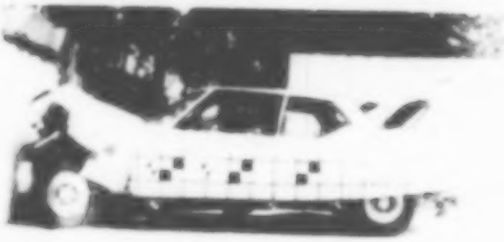
This improvement stems, in part, from the difference in the vehicle's architecture:

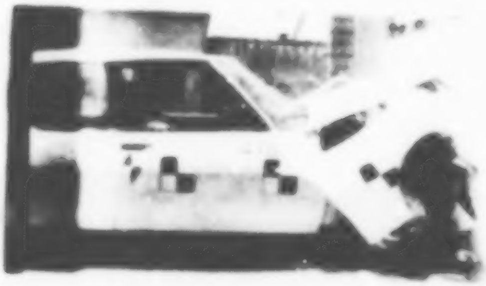
Front axle with pulled arms, notably, a relatively great percentage of the mass situated towards the front of the vehicle *comes into contact very early in the impact against a fixed barrier.* The resulting force diminishes while maintaining a short application time.

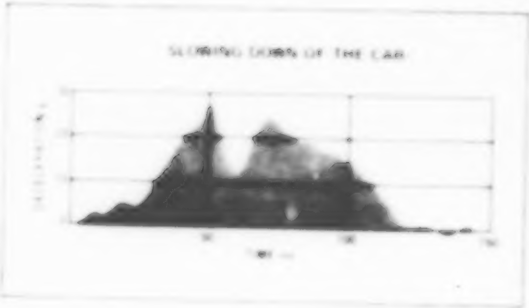
The **SM** coupe belongs to the category of vehicles offering in the section of the vehicle a distortion possibility that – after impact – provides *quite an acceptable amount of survival space.*

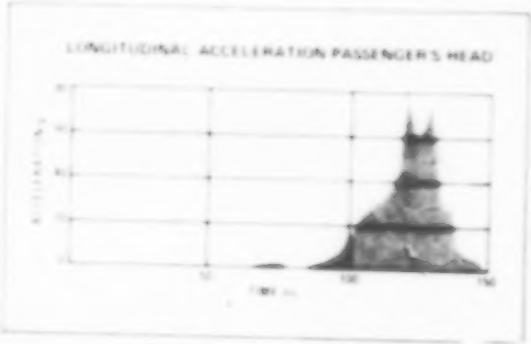


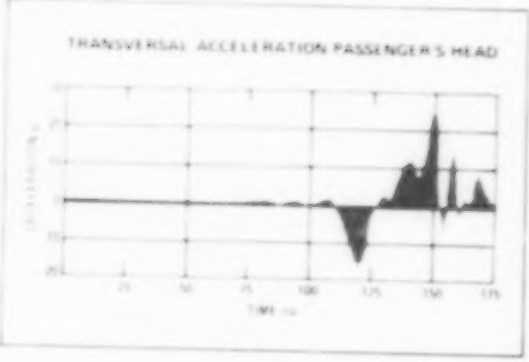


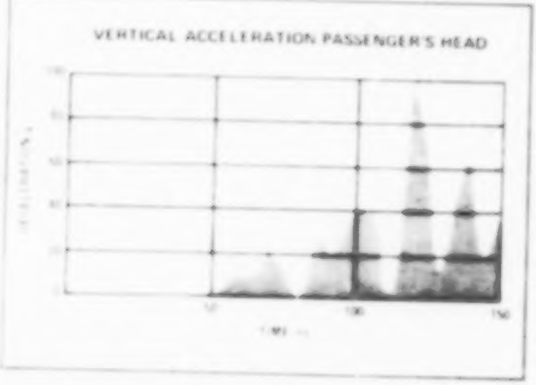





SLOWING DOWN OF THE CAR


LONGITUDINAL ACCELERATION PASSENGER'S HEAD


TRANSVERSAL ACCELERATION PASSENGER'S HEAD


VERTICAL ACCELERATION PASSENGER'S HEAD

SM COUPE

TEST C 420/71

PERPENDICULAR FRONTAL IMPACT

v = 50 km/hr

PRELIMINARY TEST OF AIR BAGS CARRIED OUT IN COLLABORATION WITH EATON

Driver's side

Air bag: 50 l with 2 diaphragms ø = 45 mm and 2 ø = 50 mm

Anthropomorphic dummy: SIERRA model 50% masculine

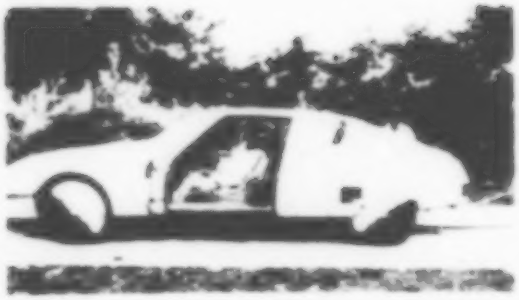
Passenger's side

Air bag: 150 l, with 4 diaphragms ø = 40 mm diffuser L = 300 mm

Anthropomorphic dummy: SIERRA model 50% feminine

Crush of the vehicle = 78 cm

• triggering of air bag at	27 ms
• beginning of inflation at	31 ms
• completion of inflation at	41 ms



Duration of the impact: 100 ms

MAXIMUM DECELERATION OF THE VEHICLE AT 58 ms = 94 g

Summary of the results calculated according to Standard 208

TABLE 8

DRIVER			
Severity index head	Maximum deceleration during 3 x 10⁻³ s chest	Stress on the thigh bones	
		right	left
273	66g	570 kg	900 kg
PASSENGER			
Severity index head	Maximum deceleration during 3 x 10⁻³ s chest	Stress on the thigh bones	
		right	left
427	53g	580 kg	520 kg

FOURTH PART

FILMED DOCUMENT
AGGRESSIVENESS TOWARD PEDESTRIANS

GS SEDAN

TEST No. 558 **AGGRESSIVENESS TOWARD PEDESTRIANS**
v = 15 at 20 km/hr

In our progress report, we aired our views concerning the *diminution of aggressiveness in the front section of the vehicle.*

The GS sedan concretizes the simultaneous adoption:

of rounded form for the front bumpers,
of the slanting hood,
of the very slanted windshield.

The sequences of aggressiveness to pedestrians that we are presenting:

from the side,
from the front,

show our conception to be favorable.

In both situations of impact, the dummy is, during the first phase of the impact, *projected onto the hood;* its head comes into contact with an *easily distorted sheet metal.*

The second phase following the braking operation shows us the dummy *sliding towards the front of the vehicle.*

FIFTH PART

FILMED DOCUMENT
LATERAL PERPENDICULAR IMPACT

GS SEDAN

LATERAL PERPENDICULAR IMPACT
GS SEDAN AGAINST GS SEDAN

We test in lateral impact between vehicles of a same recent conception comprising at the floor level an integrated rigid structure:

Hollow frame members of relatively great dimensions.
Cross-bars under the seats.

In the course of the tests that we are showing here the vehicle colliding into the stationary vehicle at two speeds:

29.5 km/h
44 km/h

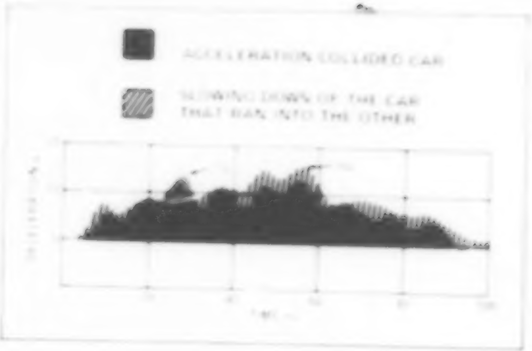
We noticed the measures of impact:

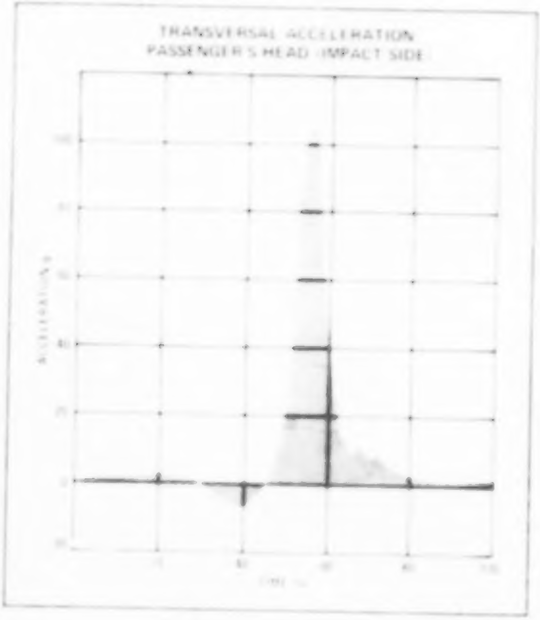
deceleration of the colliding vehicle 16 g
acceleration of the stationary vehicle 13 g

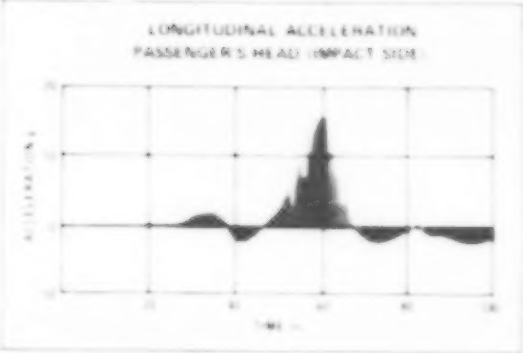
Shows the homogeneity of the vehicle insofar as its aggressiveness (the front) and its side rigidness is concerned.

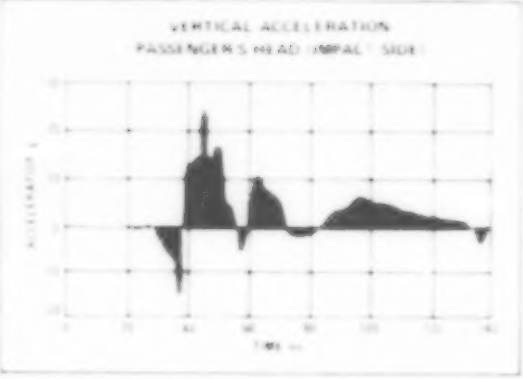
The "severity index" according to GADD C.W. comes to 744 in the head of the dummy on the side receiving the impact without any special protection.

The peak of transversal acceleration is due to the impact of the head on the upper fastening of the "function safety belt" that holds the dummy onto its seat.









GS SEDANS

TEST No. 556 PERPENDICULAR LATERAL IMPACT

v = 32 km/hr

SIMULATION IN TEST LABORATORY

The Engineers of the Research and Study Department must be able to test as soon as possible the product they have conceived.

To simulate the lateral impact the pendulum ram seems to be the most economical solution with a simple and rapid set-up.

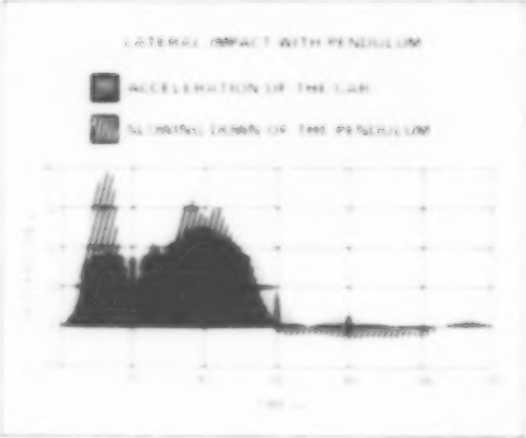
The pendulum ram is described in the presentation of the test of absorber-bumpers on the front section of the vehicle.

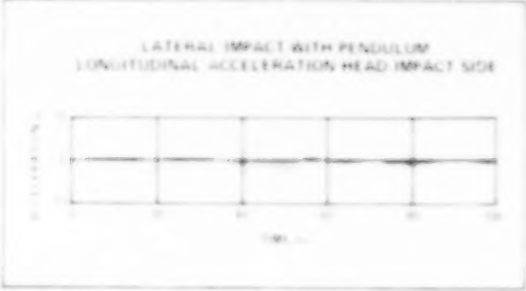
The tests enable us to measure:

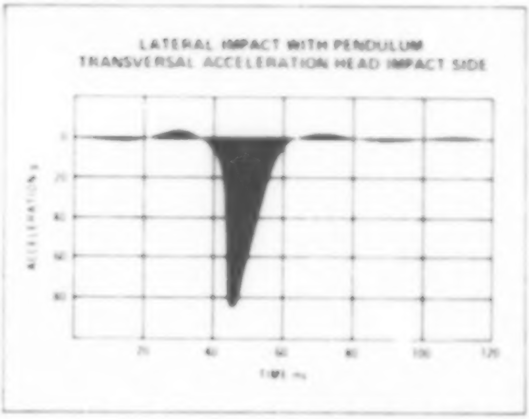
- the impact speed
- the deceleraton of the head
- the acceleration of the vehicle that is hit.

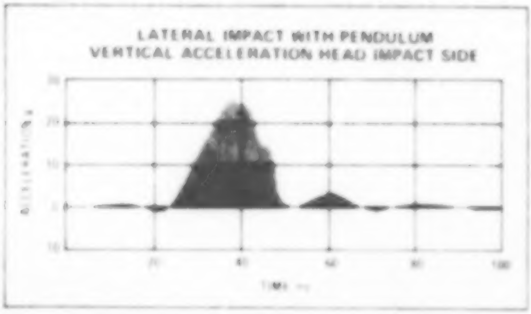
The two dummies inside allow us:

- to analyze through films their kinematics during the impact
- to measure the accelerations within the head of the dummy on the impact side notably.









This procedure allows a rapid check of the influence of eventual structural modifications to be made.

The pendulum ram of course meets with requirements for simulations of oblique lateral impact.

We note during the simulation test a good correlation with the real impact.

PERPENDICULAR SIDE COLLISION, VEHICLE AGAINST VEHICLE

v = 32 km/hr

We are showing two types of side collision:

a GS sedan (2000 pounds) against a Dyane (1500 pounds)

a GS sedan (2000 pounds) against a DS sedan (2600 pounds)

The curves

of deceleration of the colliding vehicle

of acceleration of the vehicle that is hit show the influence of the mass upon the behavior of the vehicles.

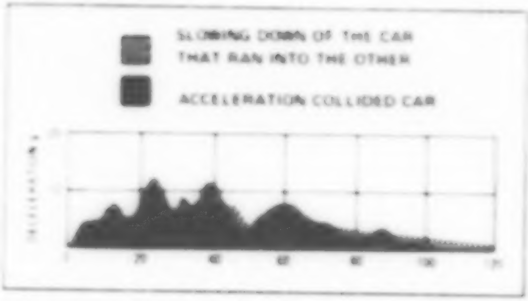
The deceleration of the colliding GS sedan is greater when the vehicle that is hit is the DS sedan.

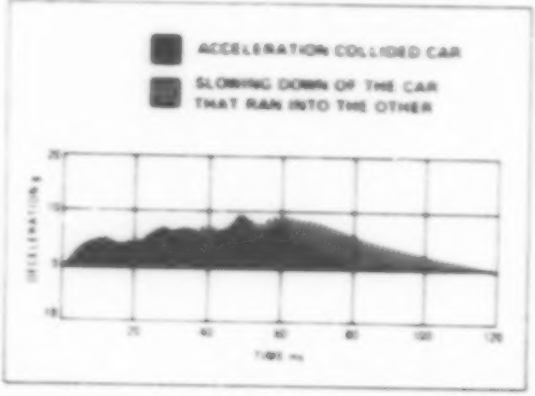
However

the acceleration of the Dyane that is hit by the GS sedan is greater than the acceleration of the DS sedan.

The car of lesser mass, upon moving, in the direction of the shock, more than a car of greater mass, stands up relatively better during side collisions if the colliding vehicle is not too aggressive.

It appears that the concept of the aggressiveness level will be granted its importance when all constructors admit its interest and value.





HOMOGENEOUS SAFETY AMID HETEROGENEOUS CAR POPULATION ?

MR. PHILLIPPE VENTRE, *Structures and Safety Engineer*

The Renault State Owned Works

INTRODUCTION

The compatibility of vehicles when colliding and especially of small and large cars in bad accidents, besides being one of the most difficult problems that manufacturers have to face, is also one of the most important to be resolved because of:

- *Its statistical importance* – In France, more than 60% of people involved in accidents are in accidents between vehicles.
- *Its social importance* – The thought that one day, in the whole world and particularly in Europe, all vehicles will be of the same size, weight and performance is not possible. Vehicles will thus remain quite assorted.

There are many difficulties:

- *Technical* – Mechanical laws exist and a first analysis shows that a small moving body will always come off worse when colliding with a big one. Only a detailed analysis of actual conditions of structural behavior in vehicle/vehicle collisions will allow solutions to compatibility problems to be found.
- *Statutory* – The compatibility aspect of the question has been totally ignored as far as legal regulations are concerned. This can be understood from the need to take measures at short notice while not having all the necessary information. But, and this is more serious, this problem of compatibility has been partly ignored in programs, the merits of which are to promote advanced technologies but the aims of which are to act as a basis for future regulations. We shall see further on, in the analysis of the different technical aspects concerning this compatibility, that some specifications of the statement of work are in opposition to any possible compatibility.

Recent action has even tried to show that insecurity of small cars is inherent in their design. Using injury rate expressed in terms of vehicle weight is an arbitrary way of presenting the problem for it has not been proved that small vehicles are involved in as many accidents as the larger ones. Furthermore, it is perfectly logical that, at present with absolutely no regulations for harmonizing results of collisions between vehicles having different characteristics, the results should be worse for the smaller vehicle.

The first step towards compatibility was made during the first ESV Conference, by introducing the idea of aggressiveness. This brought a new way of looking at the problem by:

- Taking account of all the people involved in an accident, not just those in one of the vehicles.
- Showing that a vehicle can itself be a danger to people outside the vehicle.
- Showing that the problem of compatibility exists even for vehicles having similar characteristics (this latter problem proven for side collisions).

Our aim now is to see how we stand with practical and theoretical research work accomplished by us for analyzing the problem of aggressiveness in frontal collisions and the different ways to finding solutions that may be presently foreseen.

EXTENSION OF THE CONCEPT OF AGGRESSIVENESS – GENERAL AGGRESSIVENESS

The presented idea of aggressiveness concerning side collisions was, in this case, obvious seeing as how the vehicle colliding had a large quantity of metal in front of the occupants whereas the occupants of the vehicle collided with were protected by only a small quantity of material. Furthermore, this situation, which was already less favorable for the occupants of the vehicle collided with, could be even worsened by the design, style and stiffness of the front part of the colliding vehicle. This first analysis already showed that an incompatibility could exist between the increase in legal requirements in frontal collisions and the concern for protecting occupants collided with in side collisions.

Analysis of real accidents shows that the idea of aggressiveness may be taken in a general sense and that it concerns all types of collisions. We intend covering here the case of the frontal collision because, statistically, it is the more important, but it is certain that the ideas and conclusions of this paper are transposable whatever the type of collision may be.

Studying of accidents and dissimilar vehicles has brought us to distinguish three types of aggressiveness:

- stiffness aggressiveness
- aggressiveness of mass
- aggressiveness of architecture

These three types of aggressiveness may be isolated, combined or accumulated on a given vehicle.

Thus we are going to present and summarize the work carried out on these three types of aggressiveness and the solutions we may propose so that vehicles of different weights and designs may co-exist on the same roads.

HYPOTHESIS

For this work we have been led to make several hypotheses from the start to provide us with a plan of thought for we think it rather unrealistic, in short and medium term, to hope for total safety for everyone in any circumstances, whatever the price may be.

Using accident statistics as a basis, we think that if it were possible to obtain a compatibility with the mass in a ratio of 1 to 2, considerable progress will have been made. Furthermore, rather than trying to constantly increase the performance against a fixed barrier of each vehicle taken separately, we think it would be preferable for each and everyone to work in finding the best possible compatibility between vehicles. To make sure, however, that this corresponds to a progress in performance, we set on vehicles of which the passenger compartment volume is correctly maintained in a collision at 65 km/hr. The final aim, then, is that when two of these vehicles of mass 1 and 2 collide, survival be ensured for all the occupants, not only for those in the larger vehicle, and this at a closing speed, still called relative speed, to be determined by statistical studies. For our hypothesis, we have taken a speed of 100 km/hr.

The calculations and tests carried out were on vehicles not equipped with energy-absorbing hydraulic devices. Although some ESVs are equipped with such devices having a long stroke, the statement of work does not directly specify this and it is highly improbable that the majority of vehicles will be equipped with this in the near future.

We define compatibility by the possibility of ensuring equal chances of survival for all occupants of two very different vehicles in a violent, head-on collision.

Ensuring occupant survival entails action on two levels:

- maintaining integrity of passenger compartment so as to keep all available room for stopping the occupant in his movement relative to the vehicle before entering in contact with any of the stiff walls of the vehicle. This problem can be solved by acting on the structure and architecture.
- respecting injury criteria that are known at the present day. This means being mindful of occupant energy in space and, consequently, in comparison with the ground. It is thus the total speed variation of the occupant in comparison with the ground (called ΔV) that must be taken into account. In the case of a small vehicle, it can readily be seen here that the law of quantities of movement will always be against it when colliding with a heavier vehicle that will impart a final speed inverse to the initial speed and, in so doing, will greatly increase the ΔV value *without reversing the deceleration sign.*

What matters to us is occupant deceleration. It will depend on the structural characteristics of vehicles as well as on restraining devices. If we wanted to test a restraining device by reproducing a vehicle/vehicle collision on a catapult, the latter would have to have a speed variation determined by initial conditions (masses of the two vehicles and relative speed) and a deceleration as a function of time obtained by combining structural characteristics of the two vehicles.

No equivalent collision with a fixed barrier exists for the occupant.

It can be seen that, for the smaller vehicle, the fact that the speed variation is greater than half the relative speed, necessitates a better performance of the restraining device which prevents high relative speeds of compatibility from being reached in vehicle/vehicle, head-on collisions.

On the other hand, in all cases of real accidents, where a minority of dead, head-on accidents and total annulation of the relative speed takes place, the main constraint consists in maintaining passenger compartment volume and thus keeping the hope of saving occupants' lives if this volume is maintained.

To this end, we are trying to make the most of the fact that a large car has, by definition, a greater crushing distance before entering into survival space than the smaller vehicle.

The deformation distances used by us in our calculations are given only for information purposes and materializing the evolution of tendencies. We have made no hypothesis particular to the relationship between crushing distances and the integrity of survival space. We have simply seen that their importance be respected, this being confirmed by practical tests.

WORK METHOD

To carry out this work the method used consisted mainly in:

- Studying problems from their theoretical, physical and mechanical point of view using mathematical models.
- Carrying out tests either on standard production vehicles or on modified vehicles, to illustrate the calculations or serve as a basis for mathematical analysis.
- Detailed analyzing of real accidents.

We have used two types of mathematical models.

The first is a model based on mass and coefficient of stiffness of different parts of structure which allows the problem to be treated a priori, without any vehicle at one's disposal. But, a knowledge of the mechanical characteristics of structural elements applied dynamically is necessary, which is not presently the case. Its accuracy also remains questionable.

The second, which is more pragmatic since it is based on test results, requires at least one test on a fixed barrier to be made for each vehicle to be studied, but also comes much nearer to reality. Thus, from general characteristics supplied *a priori* for an imaginary vehicle, the influence of the different parameters may be studied.

Description of mathematical model used

Program of calculations on Hewlett-Packard

AIMS OF THE PROGRAM

From the results of frontal collisions with a dynamometrical buffer (presented during the second international conference on ESV in Stuttgart) by two vehicles A and B, we intend pre-determining the impact of vehicle A against vehicle B for a range of initial conditions.

Two preliminary tests are necessary.

- A frontal collision with the dynamometrical buffer by a vehicle (A).
- A frontal collision with the dynamometrical buffer by another vehicle (B).

These two "shots" must be carried out at a sufficiently high impact speed: the deformation obtained in these tests must be greater than the deformation obtained in the collision between vehicle A and vehicle B for the initial relative impact speed of ΔV considered.

Suppose vehicle A against a fixed barrier: impact speed V_A, deformation x'_A.

Vehicle B against fixed barrier: impact speed V_B, deformation x'_B.

Then x'_A must be greater than x_A
and x'_B must be greater than x_B.

Thus it can be seen why it is necessary to carry out tests at high speed to allow a wider range of initial speeds ΔV to be covered (collision between vehicles).

As a general rule, the "softer" a vehicle is, the more it will be necessary to carry out the test at high speed if the simulation of a collision of such a vehicle with a "stiffer", and heavier vehicle is to be envisaged.

From the curves of forces as a function of time, after double integration of deceleration as a function of time (or measuring on film the deformation produced during the collision), we can determine the curve for forces as a function of deformation of each vehicle.

After this, we suppose that curves F (x) obtained on the dynamometrical buffer may be used to calculate the case of vehicle/vehicle collision and thus that crushing strength of front part of a vehicle is a function of only the deformation of this vehicle and not of obstacle stiffness nor of deformation speed. This is not quite consistent with reality, especially because of masses of front part stopping against a fixed barrier in a shorter distance than the passenger compartment. However, if the F (x) curves used are filtered at a sufficiently low frequency and have no high peaks of very short duration, we can obtain agreement between calculations and tests.

PROGRAM OF CALCULATION

Theory

a) Any spring effect during the deformation phase is to be neglected.
b) The deformation face is plane and normal to initial trajectories of the two vehicles.
c) Suppose the state of deformation of a vehicle. This condition is characterized by the point M on the force-deformation curve of a vehicle.

It is necessary, to obtain an extra deformation Δy that M passes through M' ($y + \Delta y$, $F + \Delta F$), otherwise, that F passes through $F + \Delta F$ (fig. no. 1).

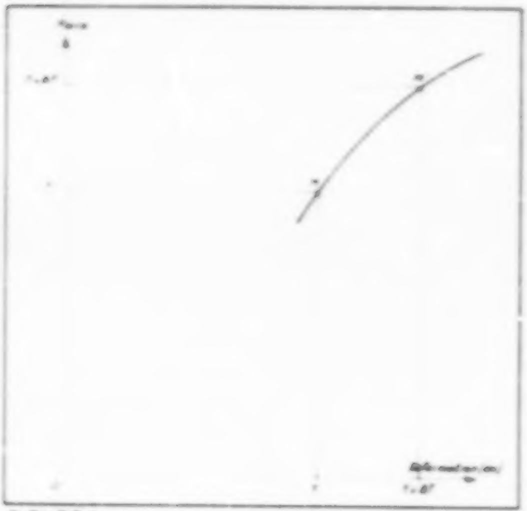


FIGURE 1

If the stress at the meeting point cannot increase because of the difference in stiffness of the two vehicles at the moment of collision considered, the deformation of the stiffer vehicle at that instant cannot increase as long as the stress necessary to pass from y to $y + \Delta y$ has not been obtained.

Notations

The axis x_A of a point linked with the non-deformed fictive part of a vehicle A and coinciding, at starting point in time, with front end of vehicle A.

X_B same definition but for vehicle B

X_M axis of deformation face (with fictitious wall)

$\left.\begin{matrix} M_A \\ M_B \end{matrix}\right\}$ Masses of the two vehicles

ϕ crushing stress exerted on structure B

V_{Ao} and V_{Bo} initial speeds of A and B

Initial conditions

$V_{Ao} > O$ with $V_{Ao} > V_{Bo}$

at $t = O$ $X_A = X_B = X_M = O$

$X_A = X_B = O$

$X_A = V_{Ao}$

$X_B = V_{Bo}$

The crushing of A against a wall is characterized by

$F_A = F_A(X_A - X_M) = F_A(y_A)$

The crushing of B against a wall is characterized by

$F_B = F_B(X_M - X_B) = F_B(y_B)$

y_A and y_B are positive deformations of vehicles A and B

Say $D_A = \dfrac{\Delta F_A}{\Delta(X_A - X_M)}$

$D_B = \dfrac{\Delta F_B}{\Delta(X_M - X_B)}$

ΔX_A increment of X_A

ΔX_B increment of X_B during the time t taken as increment for calculating

3 principal cases are to be envisaged

1/ $D_A \cdot D_B < O$ with $D_A > O$

$\Delta(x_M - x_B) = \Delta x_M - \Delta x_B = \Delta x_A - \Delta x_B$ $\phi = F_B$

for $x_M = x_B$

If the vehicle A suffers any extra deformation, it will no longer satisfy the hypothesis c/ thus it cannot be deformed as long as the stress at the meeting point $\phi = F_B$, in this case, does not pass again through the value of F_A (fig. no. 2).

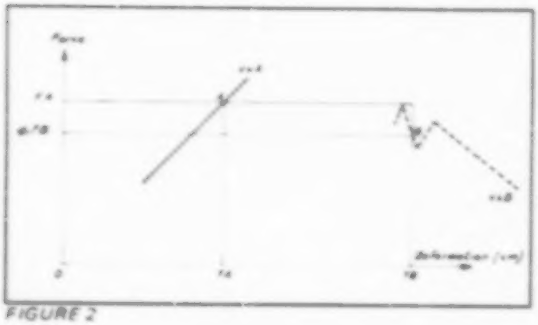


FIGURE 2

$\phi = F_B(x_M - x_B)$

2/ If $D_A \cdot D_B > O$

with $D_A > O$ and $D_B > O$

a/ $F_A > F_B$

$\phi = F_B$ the remarks concerning the preceding valid for this case (fig. no. 3).

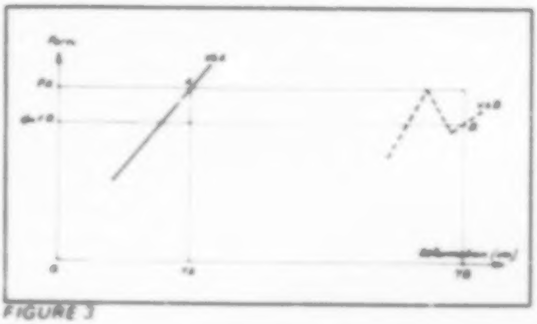


FIGURE 3

$b/F_A = F_B$

The hypothesis c/ is then satisfied: the two vehicles are simultaneously deformed. We have

$\phi = F_A = F_B$ (fig. no. 4)

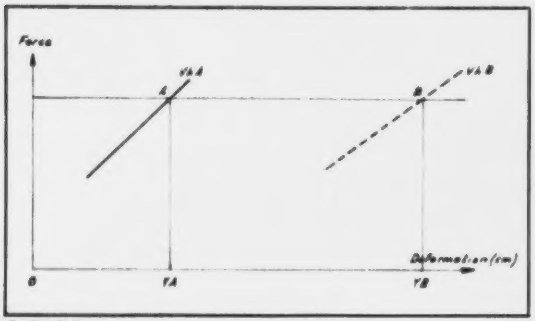


FIGURE 4

For an increase in deformations Δy_A and Δy_B, we have:

$$\Delta F_A = \Delta F_B = D_A \times \Delta(x_A - x_M) = D_B \times \Delta(x_M - x_B)$$

$$\Delta x_M = \frac{D_A \cdot \Delta x_A + D_B \cdot \Delta x_B}{D_A + D_B}$$

As soon as ϕ has been determined by numerical methods from $\ddot{x}_A = -\frac{\phi}{M_A}$ and $\ddot{x}_B = \frac{\phi}{M_B}$ all the other characteristics of the collision may be calculated.

The program of calculation, allows all the combinations between the variables to be obtained on a plotting board.

$x_A, x_B, x_M, y_A, y_B, V_A, V_B, t, \ddot{x}_A, \ddot{x}_B, V_A, V_B, \phi, D_A, D_B, y_r = y_A + y_B$.

This model allows particularly what happens over the speed of compatibility to be studied.

AGGRESSIVENESS OF STIFFNESS

By aggressiveness of stiffness we are characterizing the difference of behavior between two vehicles of equal mass and of which the crushing strengths are different.

Further on, we shall merge, in the theoretical cases, the forces exerted on the buffer which equal the sum of the products of the elementary masses by their deceleration as such, and the product of the total mass by the deceleration of a non-deformed part of the vehicle.

$$\Sigma m\gamma = M\Gamma$$

This important simplification is acceptable if the masses of the deformed parts of the two vehicles are not too different from each other in value and in distribution.

Treating the problem from the calculation point of view and based on a real test.

So as to carry out a test developing this first case of aggressiveness, we chose two vehicles from the RENAULT range, of identical mass and deceleration characteristics different against fixed barriers. They are the RENAULT 6 and the RENAULT 10. Both vehicles are quite capable of standing up to the frontal collision with a fixed barrier at 50 km/hr. But what happens when these two vehicles collide with each other?

Figures 5 and 6 show the characteristics of deceleration and forces against a fixed barrier for the two vehicles considered.

For the vehicle/vehicle test the two vehicles are pulled by a device allowing identical speeds and perfect accuracy of meeting point to be obtained with certainty.

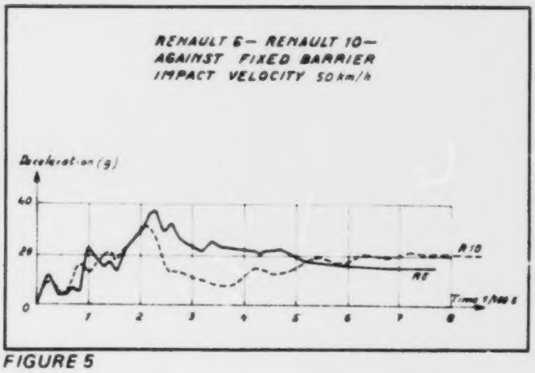


FIGURE 5

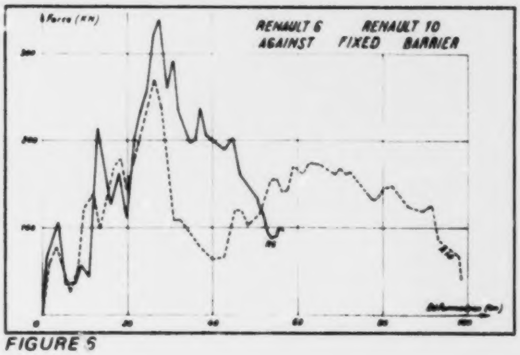


FIGURE 5

The reference test was carried out at 48 km/hr (closing speed of 96 km/hr) and so as to come as near as possible to the hypothetical calculations, we inserted a non-distortion plate between the vehicles to give an interface as flat as possible.

Figure 7 gives the decelerations recorded during tests and, as a comparison, those calculated on a mathematical model.

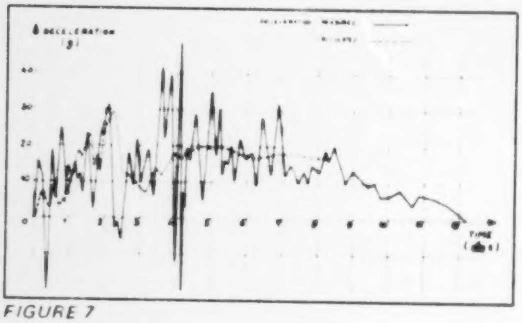


FIGURE 7

Figure 8 gives the dynamic deformation of the two vehicles during the collision which was measured on the film and calculated on the model.

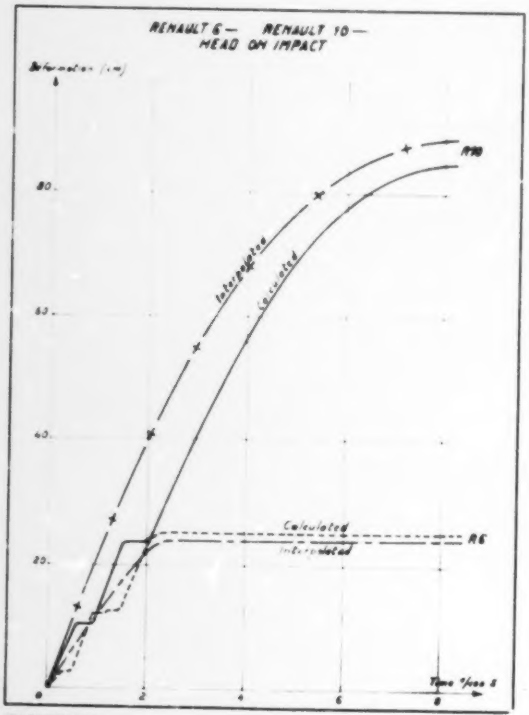


FIGURE 8

Figure 9 gives the compared penetrations for both vehicles in a case of a test against the wall and for the vehicle against vehicle test.

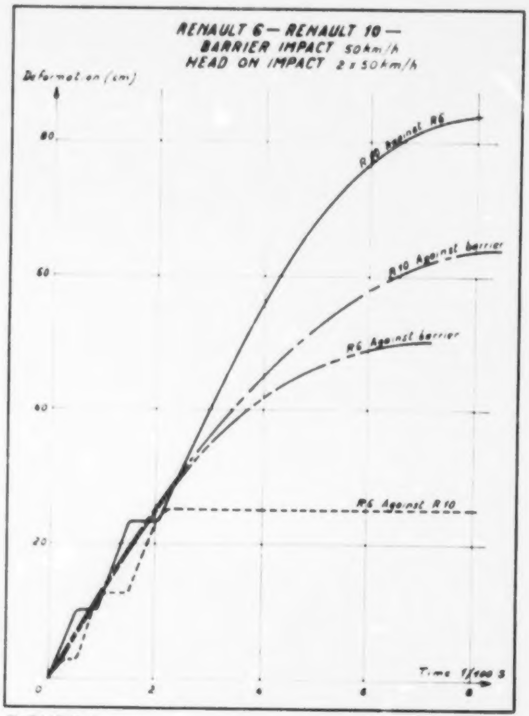


FIGURE 9

Thus, the maximum deformations are as follows:

	Maxi. deformation at 50 km/hr with wall	Maxi. deformation at 50 km/hr with R6/R10 collision
Renault 6	50.8 cm	26.2 cm
Renault 10	64.7 cm	84.5 cm

The vehicle having the smaller rate of deceleration is thus greatly disadvantaged. In this case, we say that the **RENAULT** 6 vehicle was aggressive compared with the **RENAULT** 10.

This can be clearly seen on the film taken during these tests.

(Projection of first film).

Running in slow motion, the difference in deformation of the two vehicles can be readily seen. Note the flat plate materializing the interface. If we closely examine the movement of this plate during the time the collision lasts, we can ascertain that it does not move continuously in the direction of crushing of the R 10 but is constantly stopping for short instants and, in fact, twice it even gives the impression of going backwards.

This means that, at times, it is the R 10 that stops being deformed because, momentarily, it has a stiffer zone or that the R 6 has momentarily, less stiffer zones.

This observation has led us to think it necessary to cover a wider range of speeds so as to have at our disposal a representative law for deformation as a function of impact for a given pair of cars.

The first calculations and tests having shown us a correct correlation between calculations and practical results, we used only the mathematical model developed from hypothesis.

Figure 10 shows the laws of force deformation for two different vehicles.

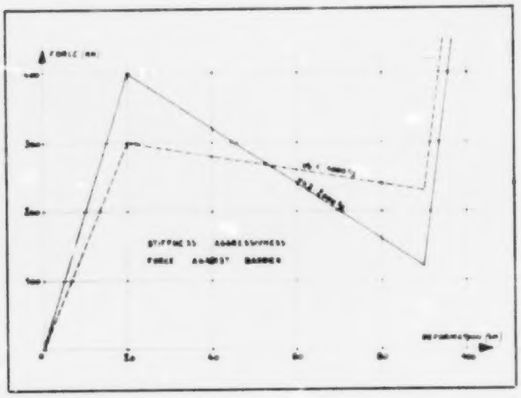


FIGURE 10

Figure 11 shows the deformation of each vehicle as a function of closing speed.

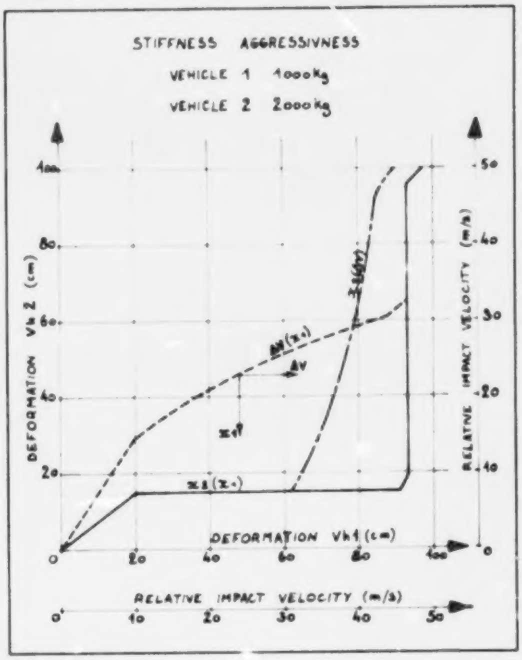
You will note that the curves cross which means that in some cases, and from a certain speed on, the vehicle stiffness characteristics are reversed and the distribution of deformation is equally modified with speed (figs. 12 and 13).

Situation for occupants

If, for a collision with fixed barrier, the deceleration of the two passenger compartments is very different (see fig. 7) the stiffer vehicle seems to favor less its occupants, for a given restraining device.

But, for the vehicle/vehicle collision having the same mass, the calculations show, and tests prove, that the passenger compartment decelerations are identical (see fig. 14).

For the occupants, the problem is brought down to maintaining the survival space of the weaker



F'GURE 11

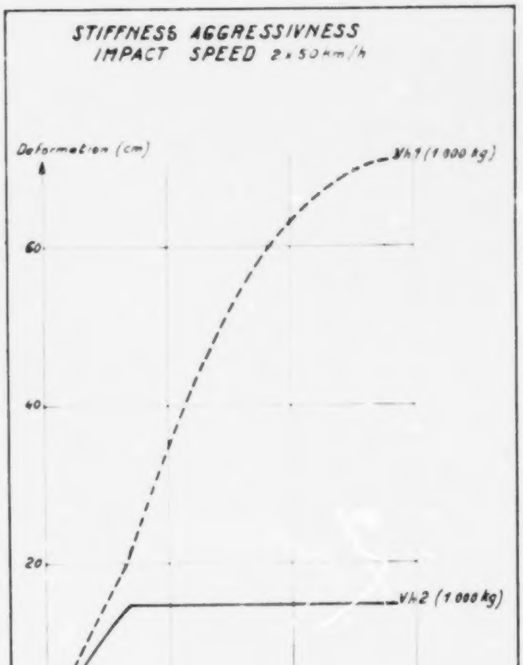


FIGURE 12

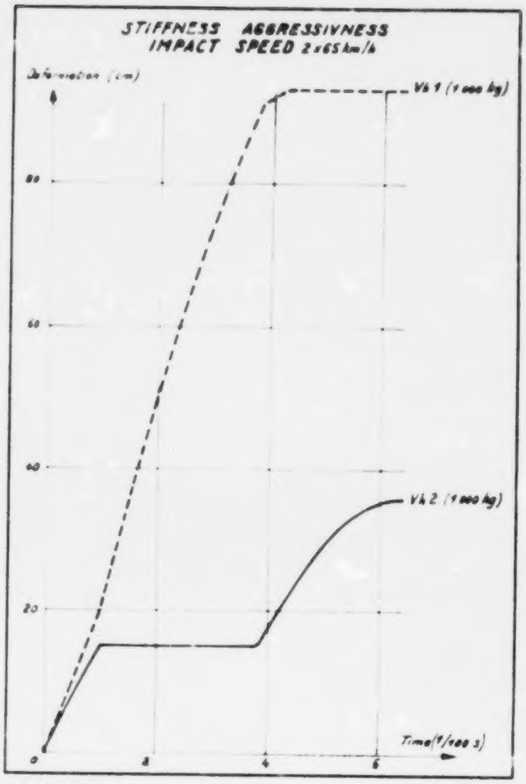


FIGURE 13

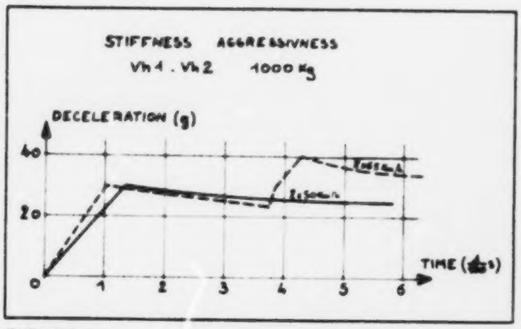


FIGURE 14

vehicle and this may be had by sufficient passenger compartment strength.

For two vehicles of equal mass using all their capacity of deformation, the mean passenger compartment deceleration obtained will be between those obtained in collisions with a fixed barrier by the two vehicles considered at half the relative speed in an automobile/automobile collision.

If a restraining device suitable for the stiffer vehicle in a collision with fixed barrier, at half the relative speed, is fitted to one of the vehicles, it will be suitable for both in the automobile/automobile collision.

First partial conclusions

The aggressiveness of stiffness is characterized by the fact that, for equal masses, a "soft" vehicle is at a disadvantage, as far as the chances of maintaining survival space is concerned, when colliding with a "stiff" vehicle.

The problem can only be solved from the structural point of view by compatibility of crushing forces of front parts of vehicle with those of passenger compartments.

On the other hand, as far as the survival spaces are maintained in both vehicles, the difference in stiffness does not make any difference, for equal vehicle masses, to the occupants.

MASS AGGRESSIVENESS

We have characterized the stiffness of a vehicle by its law of deceleration in collision with a fixed barrier and have thus seen the influence of a difference in deceleration levels for vehicles of equal mass. We are now going to study the influence of mass. We have limited ourselves to studying what happens in the case of the greatest difference in our hypothesis, i.e. for a mass ratio of 1 to 2.

In this case, for a relative speed of Vr, the ΔV value of the smaller vehicle will be 2/3 Vr, and of the larger vehicle 1/3 Vr. The energy to be absorbed by deformation of the front parts is, then, $1/3\ MV_r^2$, i.e. 4/3 of collision energy with a fixed barrier with Vr/2 for the heavier vehicle, and 8/3 for the lighter vehicle.

We have studied what happens in two cases of different stiffness:

- Both vehicles have the same maximum level of deceleration in collision with fixed barrier.
- Both vehicles have different levels of deceleration.

First case

–*Both vehicles have the same maximum value of γ.*

Figure 15 shows the laws of deceleration of each vehicle in collision with fixed barrier.

Figure 16 shows the laws of crushing forces for each vehicle in collision with a fixed barrier.

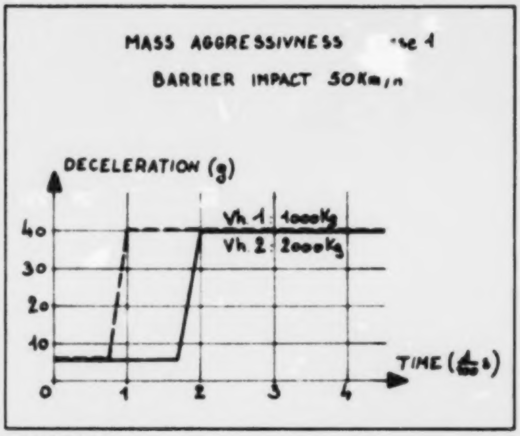


FIGURE 15

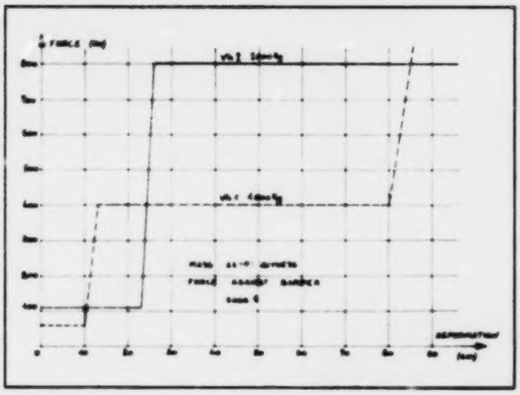


FIGURE 16

Figure 17 shows the laws of crushing for both vehicles when colliding at 50 km/hr. We can also see that, for an equal law of deceleration in collision with fixed barrier, the smaller vehicle is greatly disadvantaged in the vehicle/vehicle collision.

Vehicles	Maxi. deformation at 50 km/hr with wall	Maxi. deformation at 50 km/hr vehicle/vehicle
Small	33.9 cm	66.5 cm
Large	45 cm	24.3 cm

This remark highlights once again the anomalies brought about by a single regulation for all types of vehicles, concerning the law of maximum deceleration of a vehicle colliding with a fixed barrier as a function of impact speed with no correcting factor as a function of mass. Both of these vehicles, while complying with this regulation, will behave completely differently in a real vehicle/vehicle accident. It is unthinkable that such a situation be imposed in advance by regulation.

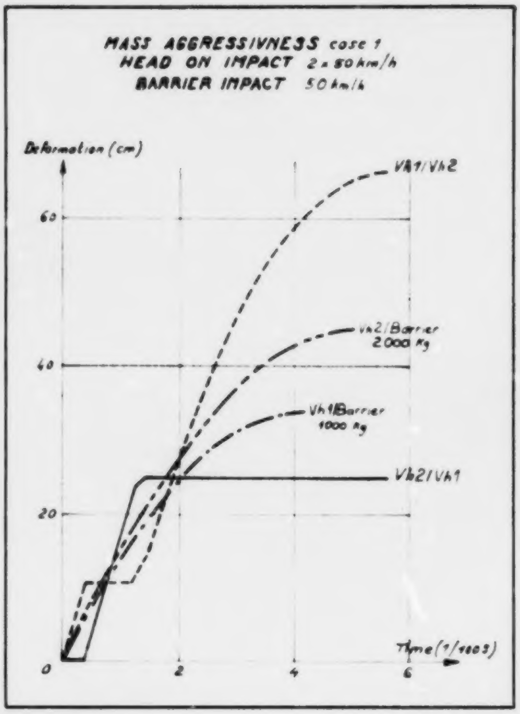


FIGURE 17

What happens to the occupants?

In the case considered above, the smaller vehicle is at a disadvantage as far as deformation is concerned which means that the problem of maintaining the integrity of survival space will be difficult to resolve. But supposing we ignore the problem of maintaining the integrity of passenger compartment; what happens to the deceleration of both these passenger compartments when the two vehicles collide? Figure 18 gives the laws of deceleration as a function of time for both vehicles. Thus it can be seen that the smaller vehicle has the greatest deceleration it can have in a collision with a fixed barrier, whereas the larger vehicle will be at half its own maximum level with a fixed barrier.

But this difference in level is not itself an anomaly if the restraining devices are designed accordingly, and particularly if the smaller vehicle is fitted with a satisfactory restraining device in collision with fixed barrier at 2/3 Vr. The occupants of the larger vehicle will undergo a more "comfortable" collision than the

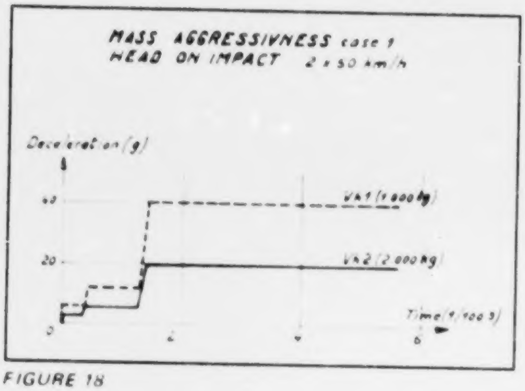


FIGURE 18

occupants of the smaller vehicle, but, on the one hand, if everybody is unhurt no damage is done and, on the other hand, mechanical laws are there to remind us that, on this point, nothing can be done.

Second case

– Both vehicles have different maximum values of γ.

We are led once again to state two cases:

- Crushing strengths are identical.
- Crushing strengths are different.

a) Crushing strengths are identical (ideal case).

Figure 19 gives the laws of deceleration for each vehicle in collision with fixed barrier.

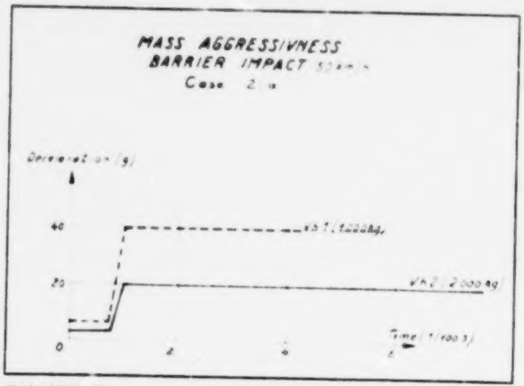


FIGURE 19

Figure 20 gives the laws of crushing strength for each vehicle in collision with fixed barrier.

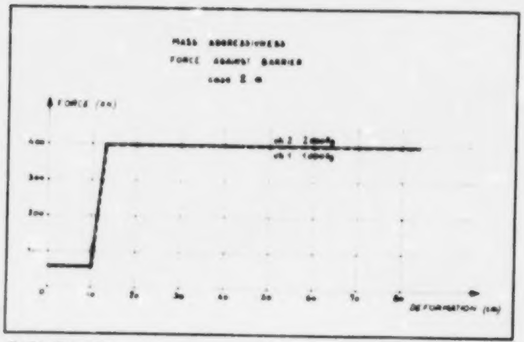


FIGURE 20

Figure 21 gives the crushing laws of both vehicles when colliding with each other.

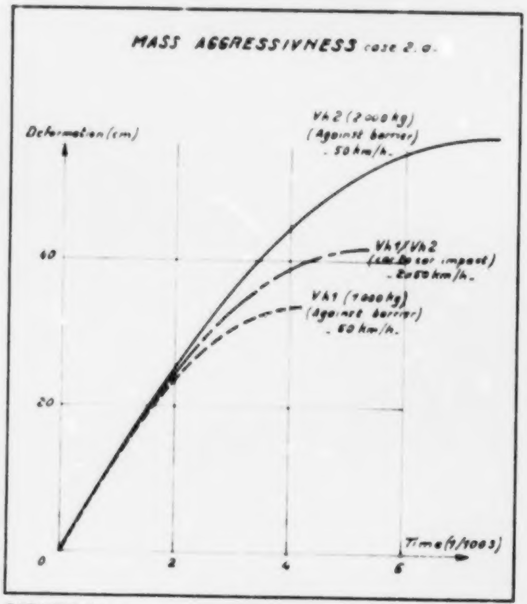


FIGURE 21

Thus we can see that in this case there is total compatibility as deformation is equally divided between the two vehicles.

What happens to the occupants?

Figure 22 gives the laws of deceleration for both vehicles. It will be noticed that these laws are identical to the case dealt with in figure 19 and that, consequently, the same comments are valid. But it will also be noticed that the problem of survival space is less acute seeing as how the deformation is more equally divided.

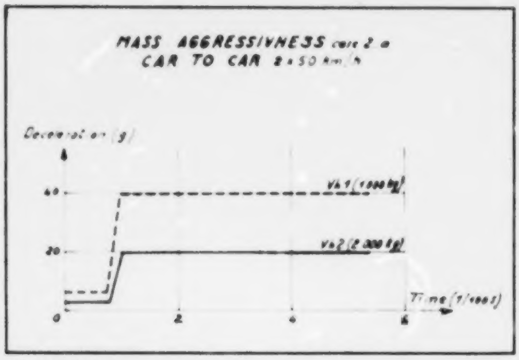


FIGURE 22

		Vh1 (2 000 kg)	Vh2 (1 000 kg)
1st. case	m γ max /wall	24.3 cm	66.5 cm
2nd. case	m F max /wall	42 cm	42 cm

b) Crushing strengths are different

Once again we state two cases:

- The lighter vehicle has a greater crushing strength than the heavier vehicle
- The heavier vehicle has a greater crushing strength than the lighter vehicle.

1) The light vehicle has a higher crushing strength than the heavy vehicle.

Figure 23 gives the γ against the wall.

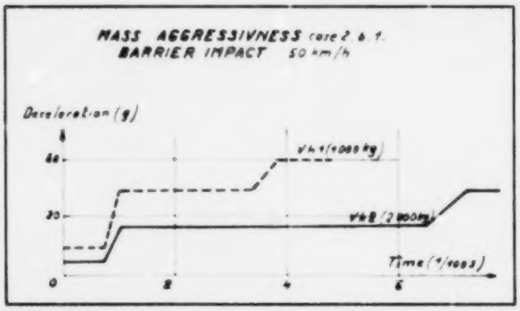


FIGURE 23

Figure 24 gives the F against the wall.

Figure 25 gives the penetrations against the wall and the penetrations vh/vh at 50 km/hr.

One can see that deformation is slighter for the small vehicle than for the big one. Results are favorable concerning the chances for maintaining survival space in the smaller vehicle.

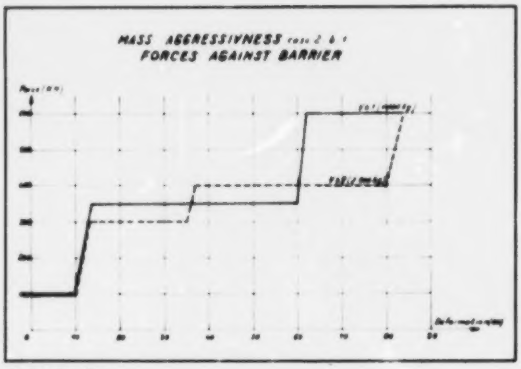


FIGURE 24

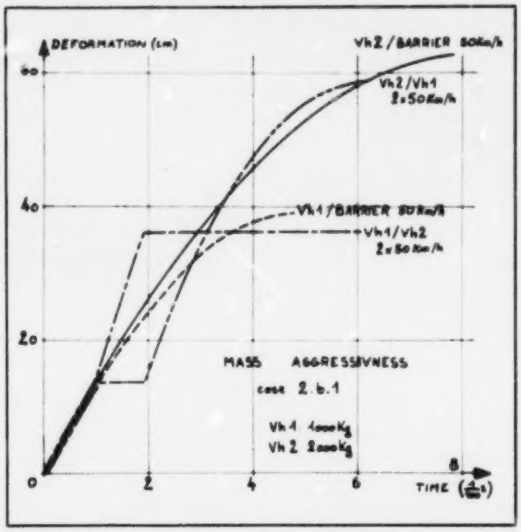


FIGURE 25

What happens to the occupants?

Figure 26 gives decelerations for the two colliding at 50 km/hr.

One can thus see that nothing has been changed concerning deceleration differences between the small vehicle and the big one. The former remarks thus remain valid. On the other hand, one has again improved the problem of survival space, since the little vehicle is even less deformed.

2) The heavy vehicle has a higher crushing strength than the light vehicle.

We did not think it interesting to study this case mathematically.

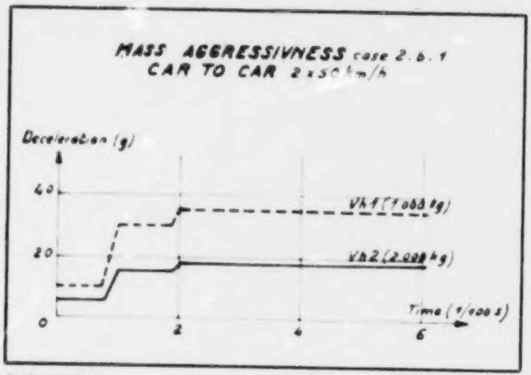


FIGURE 26

A real test on this point is very significative. (Dodge/R.5 standard Film).

In this case the result is obvious as one adds aggressivity of rigidity and aggressivity of mass on the same vehicle. This is what actually happens in numerous cases today, and it is most of all this case that must not be extended or multiplied. However, this can unfortunately be feared if vehicles weighing over 2,500 kg developing 40 g against the fixed barrier are generalized through regulations. What shall become of the millions of vehicles existing today facing these monsters?

Second partial conclusion

If one accepts the idea that there will always be vehicles of different masses, the aggressivity of mass also exists.

Its effects are of two different types:

1. Considering the structures of the vehicles, solutions are possible enabling to minimize the effects by adjusting the maximum crushing efforts according to the mass to be stopped.
2. Considering the occupants, decelerations will always be in inverse ratio to mass. This does not matter until the limit of compatibility is reached, and this is the limit for which one obtains the same level of maximum deceleration against a fixed barrier without reduction of the survival space, if restraint means are provided consequently.

What we have seen concerning the aggressivity of rigidity and the aggressivity of mass shows that there will always exist a limit of compatibility that should be fixed reasonably. It would be unreasonable to hope to render compatible the lightest vehicles with the biggest trucks. But one way toward compatibility is to master the crushing efforts according to the mass of the vehicle, and this within mass and impact speed limits well chosen.

ARCHITECTURE AGGRESSIVITY

Research work carried out to study the influence of mass and rigidity on the behavior during head-on crash between vehicles has shown the importance of a third parameter which we have named the architecture aggressivity. This involves the placing of the various important assemblies inside the vehicle, and particularly inside the front part.

In our first calculations, we supposed that the front surface of the vehicle was homogeneous and that the characteristics of the crushing forces to be considered was evenly distributed per unit area.

This was a simplification enabling a global approach of the problems involved. However, in reality, things are very much otherwise, and the effect of the important and incompressible masses disposed in the structure is considerable, and cannot be neglected.

Thus, when an engine-gearbox assembly stops against a wall, it does this by its own means. Furthermore, it only changes the deceleration laws of the vehicle carrying it, when there are connections enabling this, if not, only the characteristics of the deformable structure of the vehicle intervene.

The use of a dynamometric device enables one to register that the stopping of the engine-gearbox unit against the wall implies only a high peak of efforts.

But this is very different if the obstacle is another car, more deformable than the wall. In such a case the stopping of the engine-gearbox assembly is not instantaneous, and forms an aggressive element.

The fact that this effort peak can, according to the architecture of the vehicle, be produced near the beginning or towards the end of the crash period or of the crushing distance, constitutes thus an element of paramount importance in aggressivity characteristics.

We have chosen to show the influence of the engine-gearbox assembly because this is the heaviest and most incompressible mass of the vehicle, but one could also study the influence of the front axle with its wheels, for example.

Theoretical study of the problem

We used the same mathematical model as previously for the study of various simple cases enabling us to illustrate the hypothesis.

Vehicles having the same mass.

We also suppose that these two vehicles have the same level of maximum deceleration against the wall, thus the same maximum effort. The only difference is the position of the maximum crushing effort during penetration, which is not the same for both vehicles.

Figure 27 gives the effort characteristics during penetration for both vehicles. One may note that both maximums are 40 T, but that one is located at 20 cm penetration and the other at 40 cm penetration. Moreover, the gradients of the effort increase and decrease curves are, of course, also different.

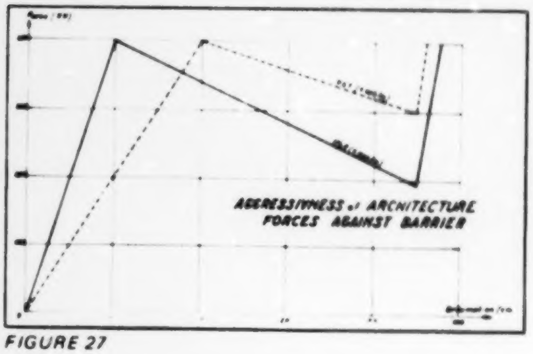


FIGURE 27

Figure 28 gives the decelerations of both vehicles against the wall.

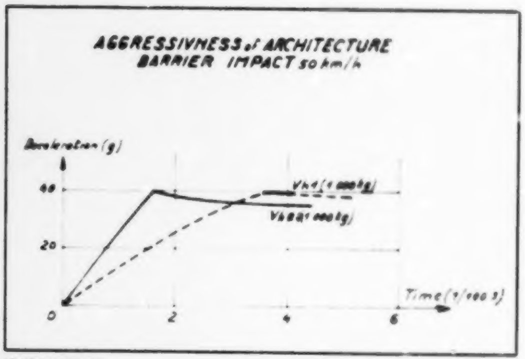


FIGURE 28

Figure 29 gives the penetration for both vehicles against a fixed barrier and when they collide. One can compare, in the table hereafter, the penetration against a wall and against another vehicle.

	Crash against wall, at 50 km/hr	Head-on crash against another vehicle at 50 km/hr
Vehicle N° 1	44.2 cm	51.32 cm
Vehicle N° 2	35 cm	27.52 cm

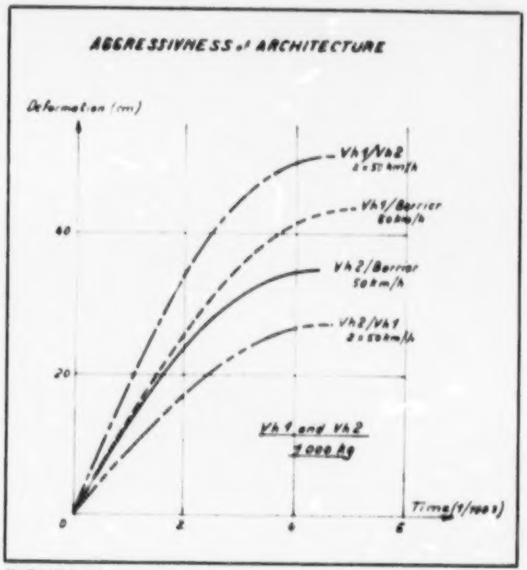


FIGURE 29

Effect on the occupants

Figure 30 gives the decelerations for each vehicle when they collide. One can check that this is identical for both vehicles as they have equal masses, and, furthermore, have the same maximum penetration for the wall crash test, but with a difference of timing. The problem is thus limited to that of the survival space.

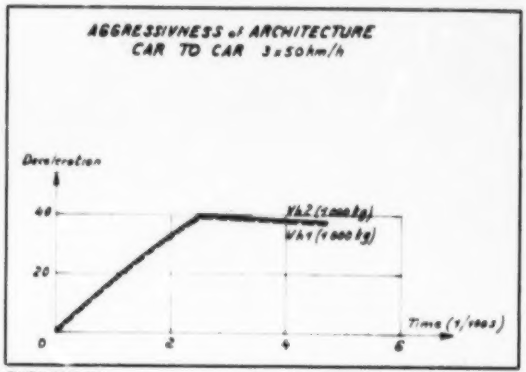
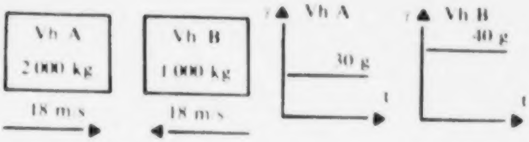


FIGURE 30

Mechanical study of the problem

It is possible to prove, in a different manner, the effect of an important rigid mass, located at a very forward position in front of the vehicle.

For this purpose, let us consider two vehicles; one of 2000 kg mass having a deceleration characteristic against the wall of 30 g, with a perfectly rectangular diagram, this is quite arbitrary but enables simple calculations. The other vehicle having 1000 kg mass, with a deceleration characteristic against the wall of 40 g, with the same type of diagram perfectly rectangular.



Both vehicles going one toward the other, at a speed of 18 m/sec (65 km/h) for each vehicle.

The Kinetic energy of both vehicles is:

$$E_{CA} = 2000 \frac{18^2}{2} = 324 \text{ KJ}$$

$$E_{CB} = 1000 \frac{18^2}{2} = 162 \text{ KJ}$$

$$E_{CA} + E_{CB} = E_C \text{ Total} = 486 \text{ KJ}$$

The residual speed at the ending of the collision will be:

$(2000 \times 18) \quad (1000 \times 18) = 300\, V_f$

thus $V_f = 6$ m/s

$$E_C \text{ final: } 3000 \frac{6^2}{2} = 54 \text{ KJ}$$

The difference of kinetic energies : $E_{c\ \text{total}}$ E_c final, represents the energy of deformation of the two vehicles A and B.

But in our hypothesis, only the vehicle B is deformed, as the deformation effort is equal to 1000 X 40 g = 40 T (the maximum effort that vehicle B can give) whereas the effort needed to deform vehicle A is equal to 2000 X 30 g = 60 T.

The variation of kinetic energy of 432 KJ is thus taken for the deformation of vehicle B which is:

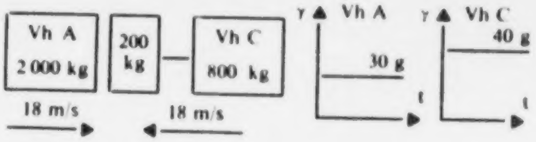
$$\text{Deformation of vehicle B} = \frac{432 \times 10^3}{4 \times 10^5} = 1.08 \text{ m.}$$

One obtains the two following deformations:

Vehicle A = 0.

Vehicle B = 108 cm.

Let us suppose now that these two vehicles are differently composed, though they keep their characteristics. We will consider the vehicle A entirely the same, but we will imagine a vehicle C, the total mass of which is 1000 kg, and giving a constant 40 g against a fixed barrier, but composed this time of an incompressible mass of 200 kg located in front of a passenger compartment of 800 kg.



To find out what is going to happen let us use the same method of calculation considering the energies involved.

We have the following elements:

$m_A = 2000$ kg $\quad V_{A_0} = 18$ m/s $\quad f_A = 6 \times 10^5$ N

$m_C = 800$ kg $\quad V_{C_0} = 18$ m/s $\quad f_C = 3.2 \times 10^5$ N

$m = 200$ kg $\quad V_{m_0} = -18$ m/s

In the first stage the mass m will be stopped by vehicle A with a deceleration of:

$$\gamma_M = \frac{(6 \times 10^5) - 3.2 \times 10^5}{200} = 1400 \text{ m/s}^2$$

It is thus activated from speed V_{mo} to speed V_A through the simultaneous deformations of A and C.

Let: $\gamma_A = 300 \text{ m/s}^2$ and $\gamma_B = 400 \text{ m/s}^2$
$V_m = -18 + 1400\, t$
$V_A = 18 - 300\, t$

$$V_m \text{ is equal to } V_A \text{ when } t = \frac{36}{1700} = 2.12 \times 10^{-2} \text{ sec.}$$

We thus have:

$V_A = V_m = 18 - 6.35 = 11.65$ m/s
$V_C = -18 + 400 \times 2.12 \times 10^{-2} = -9.53$ m/s

The displacements of the centers of gravity are then equal to:

$\Delta x_A = 18\, t - 150\, t^2 = 38.1 - 6.72 = 31.38$ cm
$\Delta x_C = -18\, t + 200\, t^2 = 38.1 + 8.95 = 29.15$ cm

The displacement of the mass of 200 kg is then equal to:

$\Delta x_m = -18\, t + 700\, t^2 = -38.1 + 31.4 = -6.7$ cm

In the second stage vehicle A becomes a mass of 2200 kg with acceleration equalling:

$$\gamma_A = \frac{3.2 \times 10^5}{2200} = 145.5 \text{ m/s}^2$$

The deformations will be finished when the relative speed of vehicle A compared with that of vehicle C, will be naught, i.e.: $V_A = V_C$

$$V_A = V_m = 11.65 - 145.5\,t$$
$$V_C = -9.53 + 400\,t$$

$$V_A = V_C \text{ when } t = \frac{21.18}{545.5} = 3.88 \times 10^{-2}\,s$$

We thus obtain:

$$\Delta x_A = 11.65\,t - 72.75\,t^2 = 45.2 - 10.6 = 34.6 \text{ cm.}$$
$$\Delta x_C = -9{,}53\,t + 200\,t^2 = 36.9 - 30 = -6.9 \text{ cm.}$$

The displacements of the different centers of gravity enables to calculate the penetration for both vehicles, which is:

Deformation of vehicle A = 38.08 cm.

Deformation of vehicle C = 63.95 cm.

One can thus see quite clearly that, without having modified the total masses nor the deceleration characteristics against a fixed barrier, the deformations of both vehicles are very different.

	Vh A	Vh B	Vh C
1st Case	0 cm	108 cm	
2nd Case	38.08 cm	—	63.95 cm

We have studied this example considering the lightest vehicle to be the modified vehicle, but of course this same demonstration is possible considering the heaviest vehicle to be the modified one. In this latter case one cumulates aggressivity of mass and aggressivity of architecture.

The examples which have just been chosen are theoretical, what is the practical significance one can give to them?

Several concrete examples enable us to illustrate these differences in architecture.

(a) Rear engined vehicles.

Comparing two vehicles having the same mass and possessing the same deceleration characteristics against a fixed barrier. Of these two, the one the most disadvantaged in the case of a head-on crash, is the one without an important and rigid mass in front.

(b) Conventional layout vehicles.

Conventional layout vehicles, the engine of which is located in the front section and connected by means of a rigid propeller shaft to the rear axle, itself fixed by more or less rigid connections to the passenger compartment mass, constitutes an example of an indeformable body located in the front section, and having a very important active mass.

(c) A too rigid and too heavy bumper bar at the front of the vehicle, studied for example for a collision against a pole at high speed, and which would not be supported by structures allowing for a low deceleration, would form in itself a danger for vehicles having a classical structure.

These few examples are sufficient to show the existence and the importance of this parameter.

Third partial conclusion

The aggressivity of architecture is not a negligible. Thus, to be concerned only with the value of the maximum crushing effort isn't enough, one must also consider its location in the penetration of the front section. This location, for a heavy and less rigid vehicle, should be as far back as possible, if one wishes to obtain compatibility at high speed.

IS COMPATIBILITY POSSIBLE?

We have analyzed the parameters that remain an obstacle for compatibility. To summarize briefly, we have seen that the following are important:

- Crushing effort for the front section of the vehicle.
- Mass of the vehicle.
- Location in the collision period, of the crushing effort maximum.

We have also shown that these factors can cumulate, and that a vehicle having all three can be extremely dangerous for the vehicles it collides with.

Under these conditions, can one still hope for compatibility between vehicles having very different characteristics?

The means to achieve this are quite clear:

For a given mass ratio, fixed after examination of the car population in the geographical zone in which one wishes to intervene, and for a given impact limit speed, which shall be fixed after examination of statistics giving the speeds at which accidents occur, it should be possible to reach a compromise, if:

- The small vehicle has a penetration effort law of a sufficiently high level, so as not to oblige the big to be too soft.
- The big vehicle has a penetration effort law slightly lower than that of the small vehicle. However, as this vehicle should have a good behavior at high speed against the wall, it should possess an important stopping effort at a

certain moment of the penetration, if this effort is not located too much forward.

So as to put this idea in application, we chose to carry out a test with the smallest model of the Renault series. We gave it the necessary modifications of structure to obtain a very good result at a speed of 70 km/h against a fixed barrier. For this end, in addition to the reinforcements for increasing the crushing effort of the whole of the front section, we also allowed the engine-gearbox assembly to move backwards freely so as to increase the deformation capacity of the whole front section of the vehicle. The engine can thus penetrate inside the passenger compartment, inside a tunnel provided for this purpose.

We then found a car, the mass of which was about double that of the Renault, and the architecture of which only needed a few modifications so as to reach the desired result. This was a conventional model with a long front bonnet, and with an engine located very much to the rear of the engine bay, but, nevertheless, its structure enabling to disperse much energy before reaching the engine.

It is important that the vehicle should not be too soft; if this is the case the slowing down of the small vehicle is insufficient and the impact on the engine takes place at too high a speed, producing important damages to the small vehicle.

The main modifications carried out on the big vehicle were the removal of the front spare wheel and the making of a few breaking chamfers on the sidemembers so as to avoid too high an effort peak before deformation.

We tested a vehicle of this type against a wall at 70 km/h, and apart from a backward movement of the steering wheel, which isn't abnormal as the vehicle did not have any particular device so as to limit this displacement, the result concerning the survival space was considered satisfactory.

We then carried out a head-on collision test between the small vehicle and the big vehicle, with a mass ratio of precisely one to two (660-1320 kg), and at a speed of 50 km/h for each vehicle.

So as to ensure the precision of both speeds and of the impact point, both vehicles were hauled in opposite directions by the same winch.

The table hereunder groups the main characteristics of the impact.

The examination of Figures 31 thru 34, photographs before and after the crash, enables to check the perfect compatibility of both vehicles on which the passenger compartments were not at all deformed, neither in the big vehicle nor in the small one. Furthermore, the four doors of the big vehicle and the two doors of the small vehicle could be opened without difficulty after the crash.

The examination of the deceleration curves of both vehicles shows that the big vehicle was not rigid enough at the beginning of the crash. The slowing down of the small vehicle thus had not been sufficient during the initial stage, and the stopping afterwards was too brutal when the crushing effort of the big vehicle became superior to that of the small one.

The penetrations of both vehicles, however, are lower than those produced against a fixed barrier, and consequently, we carried out a second test at 70 km/h. For this test we used another Renault small vehicle identical to the first model we used, and the same big model after having modified it as follows:

- Reinforcement of the front section to increase the deformation effort, and thus deceleration during the first stage of the crash.
- Modification of the propeller shaft connecting the engine to the rear axle and thus to a part of the mass of the passenger compartment. This modification aimed at making the propeller shaft telescopic and at absorbing energy, and did not present important technological difficulties.

The second test was carried out under the same conditions as the first, i.e. haulage by means of a winch of both vehicles at the same speed of 70 km/h. But in this case each vehicle contained a dummy in the front passenger seat.

The main stages of these tests are given by the following film:

1. Test of the small vehicle at 70 km/h against a fixed barrier.
2. Test of the big vehicle at 70 km/h against a barrier.
3. Collision between the big vehicle and the small one at 2 x 50 km/h.
4. Collision between the big vehicle and the small one at 2 x 70 km/h.

Length in m.		Width in m.	Weight in kg.	Max. Penetration Wall test.	Maxi. effort wall test.	Peak effort location	Maxi. γ vh/vh. g.	Maxi. Penetration vh/vh.
Small vh.	3.50	1.52	660	45 cm at 72 km/hr	54 T	18 cm.	70	25 cm.
big vh.	4.70	1.81	1 320	108 cm at 71 km/hr	84 T	59 cm	35	63 cm.

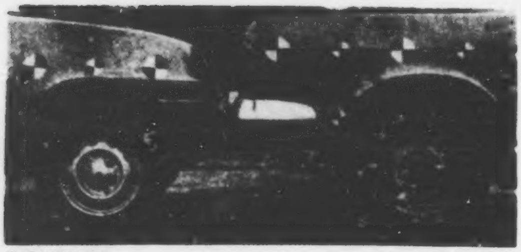


FIGURE 31

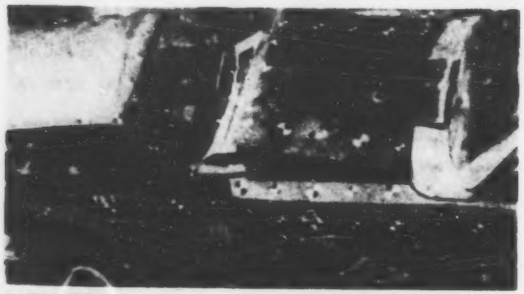


FIGURE 32

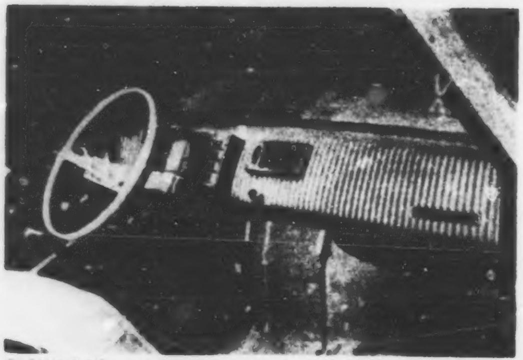


FIGURE 33

FIGURE 34

We have just examined what happened during the collision of the two vehicles at 2 x 50 km/h, let us now see the results of the collision at 70 km/h.

The examination of the vehicles (figures 35 and 36) showed that in spite of the severity of the collision the small vehicle resisted perfectly, and that immediately after the crash its doors could be opened quite normally. The survival space was perfectly maintained, and the backward displacement of the engine, quite visible in the tunnel, does not affect this space whatsoever.

For the big vehicle we reached the limits of compatibility, the doors were very hard to open, and the displacement of the column was very important, which is not surprising, as the vehicle had not received any particular preparation for this point.

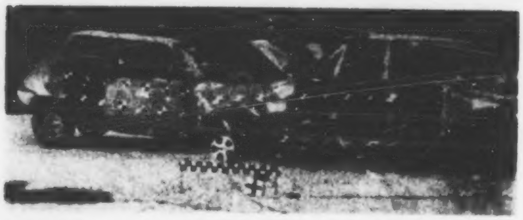


FIGURE 35

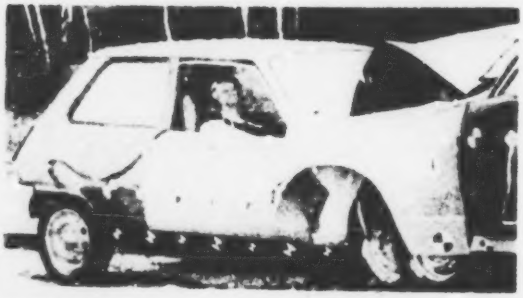


FIGURE 36

IMPORTANT REMARKS

This high speed test shows all the importance of the definition of the *compatibility limit speed* which should be fixed as precisely as possible according to the statistical distribution of accident speeds, as well as for the best *mass ratio*.

If it is thus possible that, in a head-on collision of two vehicles against one-another at speeds of 70 km/h *at the instant of impact*, that the least deformed one was the one weighing only half the other; then solutions surely exist for vehicles of different masses to offer equal probabilities of maintaining the survival volume in a common collision.

WHAT HAPPENED TO THE DUMMIES

In both vehicles the dummies were held down by belts with three fixation points. This test was mainly intended on testing the structures, and we had not prepared any very performing restraint means.

Furthermore, our lack of experience concerning restraint problems at such high speeds (the speed variation for the small vehicle was about 93 km/h) did not allow us to perfect, in such a short period, a correct means of restraint.

We thus limited ourselves to ensuring a reinforced means so as to avoid its rupture, and using an energy absorber with setting increased. We did not seek to use sophisticated devices to improve the coupling, though we knew that this would improve the results.

One should also bear in mind that this was a head-on crash in the same axis, and that speed variation is maximum in this case, which remains very particular compared with the true accidents.

However, the results were satisfactory as the dummies being firmly held down, did not hit anything at head level, and that there were only slight signs of impact at knee level with the occupant of the small vehicle.

Concerning the decelerations supported by the dummies, one can say that for the occupant of the big vehicle, the rate of deceleration was lower than that defined by injury criterion regulations.

Concerning the occupant of the small vehicle, a too high effort rating of the safety belt energy absorber stopped the sufficient displacement of the thorax in the passenger compartment, involving decelerations which were of a too high level for the head and the thorax. However, an examination of these displacements leads us to believe it possible to increase them, and thus to lower the levels of deceleration.

GENERAL CONCLUSIONS

After studying the parameters which govern the different types of aggressivity, and the effect they have on the result of a collision between vehicles having very different characteristics, one can answer that means do exist for strongly reducing the differences of behavior during collision between vehicles, and this is an important problem, as statistical data proves.

Solutions depend of course on the starting hypothesis and on the final goals, and it is possible to make both of these evolve.

However, it is certain that it will not be possible to answer all the cases of loading, masses, and speeds, and this shows all the importance of a detailed study of statistical data enabling to determine the level of disparities it is reasonable to aim at.

The solutions involved request mastering the crushing forces and the law of the variation of these forces according to penetration, with a corrective factor depending on the mass. Furthermore, we have seen all the importance of the location of the deformation effort peak in the crash period, or in the distance of penetration.

It is by combining the various effects studied here above that it will become possible to obtain compatibility between vehicles of very different types.

To this end, we use the fact that the big vehicle has by definition a longer crushing distance than that of the small one. Consequently, it should have in front a structure enabling to absorb energy, without an effort peak too high, and with an engine as far backwards as possible in the front part of the vehicle, especially if it is connected to a heavy passenger compartment through a propeller shaft, for example.

On the other hand the small vehicle should present a high crushing effort, the peak of which should be as forward as possible, the lighter the vehicle is.

Further remarks can be made concerning certain details, as for example the fact that the front bonnets should remain closed and fold, and not remain straight and strike the windscreen of the other vehicle.

A technically attractive solution to aggressivity problems does exist, but this is sophisticated: the hydraulic bumper. All the studies made on this matter show the advantage of such a solution. This can be easily explained as this enables to modulate the effort peak according to the resistance of the obstacle, and to bring backwards the location of the effort peak by increasing the length of the vehicle.

However, the weight, the price, and the installation complications of such a device lead us to believe that its use for average size vehicles, and even more so in the case of small, economical vehicles, will not be possible short term, nor even medium term. Consequently, one thus must find solutions based on more classical technologies.

It is essential that, until the ending of the works on the problems created by aggressivity, no regulation obliges the makers to adopt solutions which would be contrary to the final goals aimed at.

So as to obtain the indispensable keeping of the survival space, one should retard for as long as possible the deformation of the passenger compartment. It is thus necessary that the deformation resistance of the front section be always lower than that of the passenger compartment. In this case, all the work concerning the deformation of the front part is more aimed at modulating the deceleration that at protecting the integrity of the passenger compartment.

It results from this that compatibility must consider the *equality of the crushing strengths of the passenger compartments* between all vehicles. Difficulties arise in the definition of the degree of this strength, and the definition of its measuring. Indeed, we have considered here a head-on collision in the same axis. However, statistical data of true accidents show all the importance of the off-set head-on collision, in quantity and in severeness. It is thus important to study also this type of accident. Now this latter type of accident shows even more clearly the effect of the compression resistance of the passenger compartment, which depends mostly on that of the side of the body, as in this case only one side of the structure is subjected to deformation forces.

On the other hand, the fact that part of the potential energy of the vehicles is dissipated during the collision by a rotative movement of the vehicles, or by a continuation of the movement because of the existence of a remnant speed after deformation of the structures, diminishes noticeably the difficulty of the restraint problem. The speed variation of the occupant is indeed, in the case of an off-set collision, lower than in the case of a pure head-on collision, the problem being that of keeping the integrity of the passenger compartment.

NOTES CONCERNING THE "AGGRESSIVITY INDEX"

The question of defining an "aggressivity index" has been asked, and our analysis works have thus progressed concerning this matter, but it seems premature to make any concrete proposals. This is even more so as we have introduced a simplification, by only considering a flat front face, and it is important to separate this face into two parts, the top part and the bottom part, so as to study aggressivity in the case of an off-set collision.

It is already possible to see however, that it will have an effort peak, and the location of this effort peak in relation to the front of the vehicle, and that these criteria will depend on the mass of the vehicle.

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FRENCH DEVELOPMENTS OF RESTRAINT MEANS

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Association Peugeot-Renault

The progress developed as regards the vehicles structure must materialize in a real profit to the car occupants. The study of restraint and protection means then becomes a difficult problem which the Association PEUGEOT-RENAULT is trying to solve by testing and reviewing on its own cars every known or foreseeable system either standard or inventive, simple or improved.

The purpose of this report is to draw up a picture of the results which we have come to up to now using the various systems.

AMERICAN AIR-BAGS WITH PYROTECHNICAL GENERATORS AND WITH COMPRESSED GAS	DRIVER	PASSENGER
SEVERITY INDEX	290/1700	270/1150
ACCELERATION THORAX	40/80 g	35/60 g
FEMUR UPPER LEG	240/1600 da N	200/1200 da N

TABLE 1

It seemed quite obvious that our review should deal first of all with the results obtained on our cars with *U.S. made AIR BAGS.* The skill and advanced technological level of some U.S. manufacturers in this matter led us to merely adapt their systems on to our own European size vehicles.

1. Two basically different systems were tested:
    - The one with a pressured gas generator, with one single bottle for both the driver and front passenger and a knee restraint upholstered iron plate. The disadvantages of this system are: the noise, the volume, the need for substantial change in the steering column and dash board.
    - The other with a pyrotechnical generator and knee restraint upholstered iron plate for the driver and a mixed generator for the front passenger, with a smaller knee restraint bag attached to the main air bag. The major problem with this system is that of toxicity.
2. Performance data are to be found in Table No. 1: the injury criteria worked out according to our tests are quite widespread and show in many cases over the 1000 value. The same applies to efforts measured at knee level, which show a very unsteady intensity often exceeding the physiologically acceptable limit.

These results show that even with elaborated systems profitting by the U.S. manufacturers' experience, an important perfecting has to be done for Air bags to meet correct, repeatable and satisfactory results for the safety of occupants in our vehicles.

Due to these circumstances, and considering our lack of direct action as regards U.S. System technology, we have tried together with the "Societe Nationale des Poudres et Explosifs," to develop a *SNPE PEUGEOT-RENAULT AIR BAG* pyrotechnical device much more adapted to the volume and dimensions of our vehicles.

1. With this system, the gas is generated by a propellant, the cooling obtained with a water based liquid, and the gas distribution inside the bag through a spray device (see Figure No. 1):

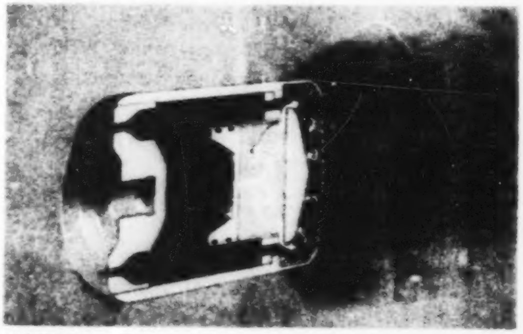


FIGURE 1

An igniter in contact with the propellant is placed crown-like around the cooling cylinder. Gases are directed towards a piston which pushes the cooling liquid into the mixing chamber on the one hand and towards the pipe on the other hand in order to spray the cooling mixture (see Figure No. 2).

FIGURE 2

A 50 liter bag is fitted onto an energy absorbing steering column facing the driver. A particular folding makes it possible to reduce the violence of gas jets. A 120 liter bag faces the front passenger, which is folded "accordian like."

The sensor is of a usual standard type (A.C. ELECTRONIC).

This system is further improved by a new protecting panel that limits the effort at knee level to 400 daN. (semi-cylinder shaped distortable girder upholstered with foamy material).

2. The test results at 48 km/h (30 m.p.h.) against fixed barrier are to be seen on Table No. 2 showing that despite some unsatisfactory tests, performances are similar to those obtained with U.S. made Air Bags. Results are a little less widespread because these devices are far more adapted to our cars. But injury criteria still show high levels.

AIR-BAGS PEUGEOT – RENAULT – S.N.P.E. WITH PYROTECHNICAL GENERATORS	DRIVER	PASSENGER
SEVERITY INDEX	660/1140	640/1360
ACCELERATION THORAX	50/72 g	48/66 g
FEMUR UPPER LEG	380/550 da N	380/420 da N

TABLE 2

The rake and distortion of the steering wheel plays a great role, at least as important as that of the energy absorbing column.

All temperature and pressure problems are not solved: in some cases, the bags happened to burst out. On the other hand, the gas is hardly any poisonous: the carbon oxide percentage diluted in a supposedly proof vehicle cannot cause any more than a strong headache.

The advantages of such an Air Bag system rely mostly in a much easier fitting of the bag (reduced mass and volume) and in a reducing of the noise: Figure No. 3 shows that sound level has been brought down from 168 dB to 150 dB with this new generator. This gain is due to the different form of pressure laws at the outlet of pressured gas and pyrotechnical generators.

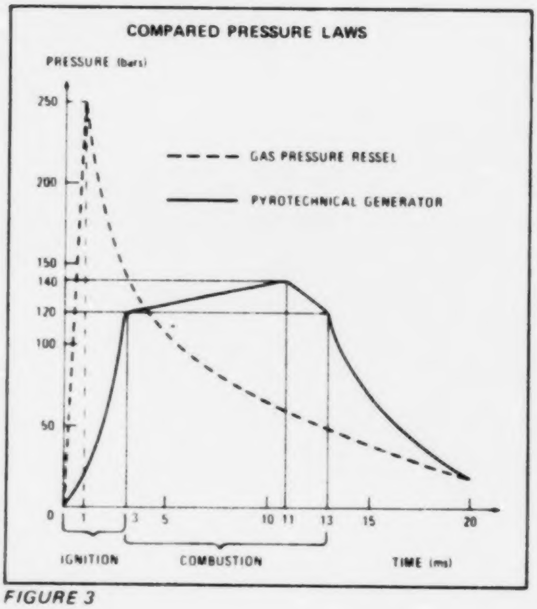


FIGURE 3

Following a much longer term policy and an inventive idea from the SERAT (Societe d'Etudes de Realizations et d'Applications Techniques) we have considered an OUTSPREADING CUSHION PANEL system protecting the occupant. We should underline here the fact that this is quite a recent idea, and that we have not yet worked it out farther than the research stage.

1. Figure No. 4 shows that this device is made up of closed bags folded on top of one another and inflated by a pyrotechnical mixture contained in each bag. It is fired by a wire network electrically supplied by the impact sensor. Firing occurs in many places at a time, since all bag networks are connected parallel.

   Cushion panels may be worked out to develop according to various volumes:

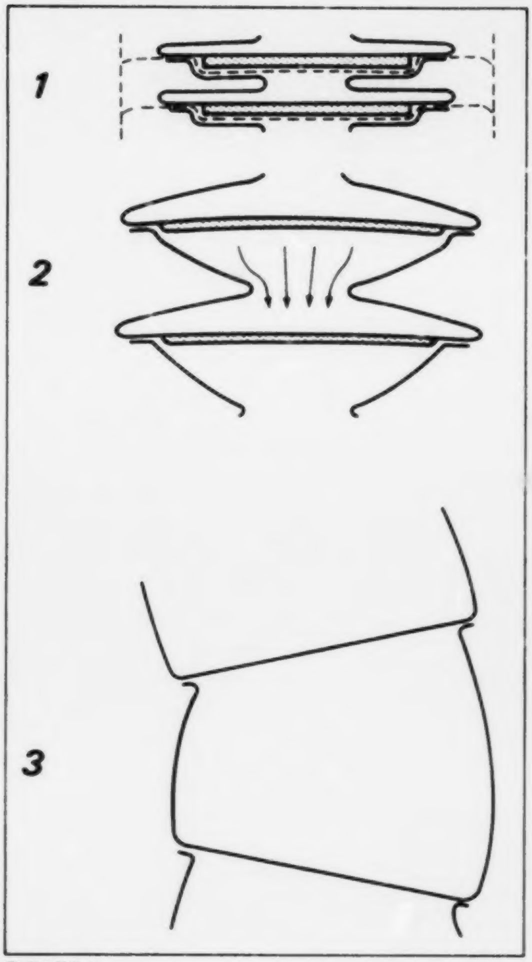


FIGURE 4

- Figure No. 5 — on the dashboard like an Air Bag, which may eventually deploy around the steering wheel.

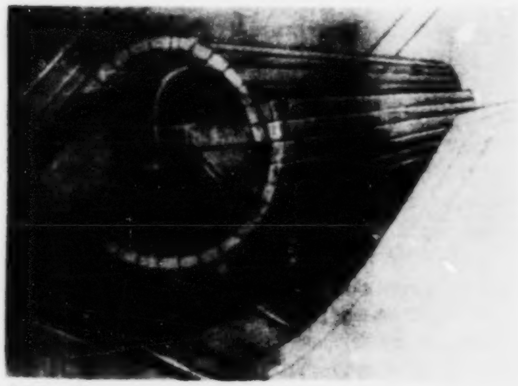


Figure 5

The volume may be made up with 2 cushions spreading out in a circle and which override when inflaction has ended.

- Figure No. 6 — around the passenger, thus causing very efficient individual protection. The cushion panel spreads out from the seat back, turning around an axle fixed with straps.
- Figure No. 7 — along the vehicle inner front and sides like a thick cushion made up with multiple bags. This protection may be placed onto the inner-roof, before glass surfaces (with distortable Safety glass) along doors, etc . . .

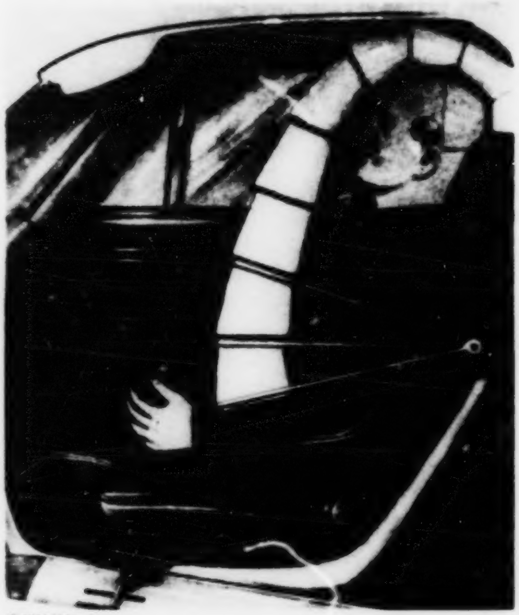


FIGURE 6

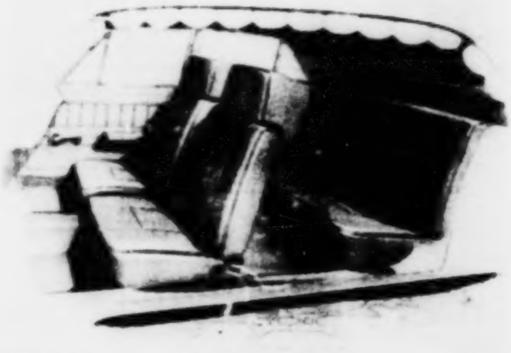


FIGURE 7

2. Even though up to now, tests have been conducted with pre-deployed cushion panels, results are rather satisfactory as may be seen from Table No. 3.

OUTSPREADING CUSHION PANEL		
	INJURY CRITERIA	MAXIMUM FORWARD MOVE
HEAD	500/800	38/45 cm
THORAX	40/50 g	35/40 cm
FEMURS UPPER LEG	400/550 da N	15/17 cm

TABLE 3

I would like to add here that such a system may be expected to reduce some Air Bags disadvantages such as the noise level (less reduced inside) efficiency in case of multiple and different shocks (the cushion remains inflated) gas poisonousness, etc. . .

Finally, we proved most interested in what we still consider today as the most concrete reliable and realistic restraint means: I mean to safety belts.

The work carried out on either U.S. or French made Air Bags still remains at the research and study stage. And in this concern, the outspreading cushion panel idea is lagging even farther behind!

Well, we have then tried and defined what could prove to be an **IMPROVED SAFETY BELT** mainly as regards performance.

1. We looked for this improvement in:
   - stiffening the strap (5% lengthening instead of 13% with a 1000 daN static load) in order to reduce the occupant's moving inside the vehicle (thus avoiding second shocks). This stiffening compensates for the baneful effect of retractors in this field.
   - manufacturing the belt with an energy absorbing fiber (strand breaking fiber) sewed parallel on to one of the torso lap buckle thus limiting the effort to a reasonable acceptable and determined value for these new conditions. The "effort/displacement" relation has a trapezoidal shape and is calibrated for 800 daN in dynamics.

     It should be pointed out here, that this system which is fitted onto our car at present profits by much experience and adjustment.
   - in adding a system that improves the men-vehicle coupling and which may be either pyrotechnical jacks tightening the strap at the very first moment of impact by a play take up, or knee protection devices preventing any "submarining" and absorbing energy at the bottom part of the body, thus relieving the strap of part of its load.
   - Finally, preventing the steering wheel from jerking up by means of a special steering column and front structure (or if needed fitting it with a pyrotechnical device that will cause it to collapse) and in fitting it with an absorbing material, that proves efficient in case of impact.
2. The tests results as to the influence of leg, wheel, and strap-play protection are to be found in Table No. 4. It shows a substantial reduction of injury criteria when using a leg protection system, and especially when the safety belt strap is not tight, which is by no means quite interesting.

IMPROVED SEAT BELTS – INFLUENCE OF KNEE-RESTRAINT					
		DRIVER		PASSENGER	
		MASS PRODUCTION STEERING WHEEL	MODIFIED STEERING WHEEL	STRETCHED SEAT BELT	LOOSE SEAT BELT
SEVERITY	WITHOUT RESTRAINT	1100	870	600	> 700
INDEX	WITH RESTRAINT	640/780	680	730	485/620
ACCELERATION	WITHOUT RESTRAINT KNEE	44 g	46 g	37 g	47 g
THORAX	WITH RESTRAINT KNEE	40/42 g	46 g	40 g	39/49 g
FEMUR	WITHOUT RESTRAINT	550	—	200	—
UPPER LEG	WITH RESTRAINT	300/400	450	400	450

TABLE 4

Table No. 5 shows the importance of prestretching the strap at the beginning of the impact. Acceleration levels and injury criteria are thus quite reduced, due to the men-vehicle coupling high quality. It may be noted from Figure No. 8, that the head angle speed inside the occupant space is reduced by half.

IMPROVED SEAT BELTS – INFLUENCE OF PRE STRETCHING			
		DRIVER	PASSENGER
SEVERITY	WITHOUT PRE STRETCHING	960/1400	720/1600
INDEX	WITH PRE STRETCHING	280/700	280/700
ACCELERATION	WITHOUT PRE STRETCHING	48/52	39/65
THORAX	WITH PRE STRETCHING	32/41	32/4
FEMUR	WITHOUT PRE STRETCHING	190/360	160/500
UPPER LEG	WITH PRE STRETCHING	0	0

TABLE 5

I would like now to show you some parts of films on the Association **PEUGEOT-RENAULT**'s work as regards occupant protection, the first results of which I have just summarized.

But before we get to see these films, I would like to draw a few provisional conclusions:

- Air bags, either U.S. or French made, still give too widespread results as yet to be industrially accepted onto our vehicles.

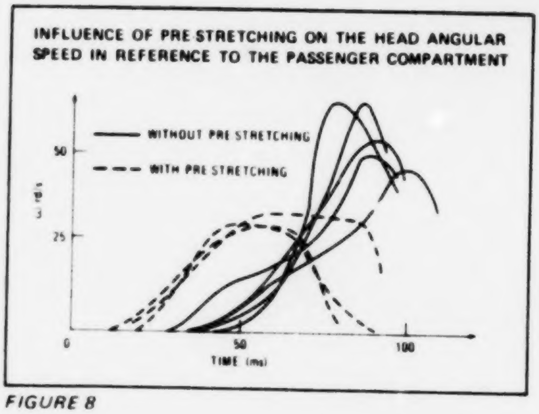

INFLUENCE OF PRE STRETCHING ON THE HEAD ANGULAR SPEED IN REFERENCE TO THE PASSENGER COMPARTMENT

FIGURE 8

Moreover, some major problems such as inefficiency as regards different multiple impacts or reliability have not yet been solved.

There still remains much to be done! Even though some progress was realized as concerns dimensions, weight, noise or toxicity.

- Outspreading cushion panels show quite interesting but difficult to master in the long run, and it is still too early for the moment to draw any prospect on this device.
- While looking for real safety, we think improved safety belts are today one of the best protection means provided we can indulge more people in wearing them. We feel convinced that the best possible way to meet this aim is to improve their acceptability and reduce their "constraining" aspect.

CRITICAL REVIEW OF ESV PROGRAM TECHNICAL TRENDS AND FUTURE RESULTING LEGISLATION

MR. CLAUDE PROST-DAME, *Commissioned Assistant for General Director*

The Renault State-Owned Works

As Director of Renault Body Engineering, I was to introduce the two speakers who have just presented to you the work of the Peugeot-Renault Association. I was thereby to outline our philosophy of road safety which is substantially different from that which inspires the Authorities of this country in setting forth the ESV profile to become the basis of future rule-making.

In view of the technical orientation of this meeting, I preferred to have this work submitted to you first, but I will now endeavor to place it within the context of our own orientations, and to explain in which respects these deviate from the ideas officially admitted here.

We do not dispute the objectives pursued. The same problems arise on both sides of the Atlantic, and unfortunate people die in the same manner. However, we are not in complete agreement as to the methods and the ways of tackling the problems.

I do not wish to treat at length the basic philosophical criticisms. The RECAT report has done so very completely (hurried schedules, incompatible with the rate of industrial development, excessive faith in the possibilities of technological research, insufficient consideration of the cost-efficiency ratio). Within the technical context of this conference, I will consider the most objective of these criticisms, and make it the starting point of my critical analysis of the orientations selected up to now.

I am referring to the disproportion existing between the extensive work undertaken in developing safety techniques, and the uncertain and fragmentary conclusions drawn up to now from the statistics and inquiries on actual accidents. However, this is where one should start to direct the technical efforts in order to achieve the best efficiency at the least cost, and as soon as possible.

It was this lack of data which probably led the Authorities of this country to define, both in the standards already issued and in the draft experimental specifications, a number of tests not necessarily representing what actually occurs on the highways.

For instance, when observing the deformation of cars in real accidents, one conceives some doubts as to the representativeness of the frontal barrier impact test, which is however the main basis of the standards and specifications in question. On the average, these deformations are often closer to those observed in experimental impacts at an angle of 30° to the test barrier.

Another example of these uncertainties is the measurement of human impact tolerance by means of Gadd's severity index. In theory since it is based on accelerations measured in the head, the reproach may be made that the kinematics of the neck and the forces tolerable by this fragile joint are neglected. In practice, the insufficient knowledge, and the poor reproduction in a manikin of the mechanical characteristics of the neck, make one suspect the reliability and biological significance of the test result.

Therefore, by following these paths, we risk producing cars at great cost which will indeed pass the "examination", but whose effectiveness in decreasing the number of victims will be neither optimum nor immediate. As a matter of fact, the search, by means of these tests, for attainment of total protection (structurally, by preserving the survival space, and by means of restraint systems), risks depriving us of the immediate benefit of devices with lesser performance, but with a sure statistical effectiveness.

This is the case of safety belts, the generalized use of which, through constraint or, better through incitement resulting from greater convenience of their use, would save a great number of lives immediately.

As we have no general statistics available for computation, we have recently analyzed a sample of accidents involving 800 vehicles. Out of the 71 deaths recorded at the R. Poincarre Hospital of Garches, not taking into account 18 pedestrians and drivers of two-wheeled vehicles, it appears that, out of the 53 deceased car occupants, 27 were ejected. Out of the 26 who remained in the cars, 19 died from impacts on the walls and, out of the 19 cases, 3 only were made more severe by occupants space deformation.

The result is therefore that, in 43 out of 53 car occupants cases, wearing the seat belt would most likely have prevented death, even in the absence of any improvement in car body strength.

It is for these reasons that we emphasize the need for promotion of safety belts. We prefer them to the hazardous air-bag, not only because they are immediately available, reliable and economical, but because as regards performance, possible improvements can keep them competitive, as Mr. de LaVenne demonstrated, not to mention their obvious superiority in the respect of ejection restraint.

However, our criticism goes further. Not only does the present orientation, based on a series of "tests", insufficiently justified by observation of real accidents, risk directing us toward too costly and too long-term solutions, to the detriment of immediate effectiveness, but it may also lead us toward aggravation of the present situation.

As a matter of fact, all these tests, based on the impact of a given vehicle against a fixed barrier, take into account only the survival of the occupants of that vehicle. On the contrary, in most accidents, there is another vehicle involved and the survival of its occupants depends not only on that vehicle's strength but also on the aggressivity of the first vehicle which might well be increased through the latter having to pass an impact test against a too severely designed fixed barrier.

We have already studied this subject in Stuttgart, citing the case of lateral impact where the difference of rigidity between the two vehicles involved proved the point. However, this is also true in the case of frontal impact, where the less rigid and lighter vehicle always undergoes the greater deformation.

Therefore, if one follows the philosophy proposed by the public authorities of this country, i.e. of a test against the crash barrier, involving more or less the same decelerations and the same deformation limits for all vehicles, one would be lead to impart to each vehicle a rigidity proportional to its weight. Thus, the lighter vehicle will necessarily be the victim in any accident involving a heavier and more rigid vehicle than itself.

In this way, one will have worked to save only half of the potential accident victims, in a socially unjust way, to the profit of the well-to-do, possessing the heaviest and most luxurious cars.

On the contrary, the study submitted to you by M. Ventre shows that, even with weight differences in a one to two ratio, one may hope to equalize the chances on both sides, by compensating the effects of weight by judiciously chosen inverse weight/rigidity ratios.

This thinking would lead to the requirement for the large car to add extra flexible length to "welcome" a small vehicle, which itself would be made more rigid, so that the survival space would be assured by extra length for the one and by extra rigidity for the other. Thus, while imparting to the large car even greater protection against fixed barrier (since this extra length would lower the deceleration), we would have distributed more equitably the chances of survival and the economic charges due to progress.

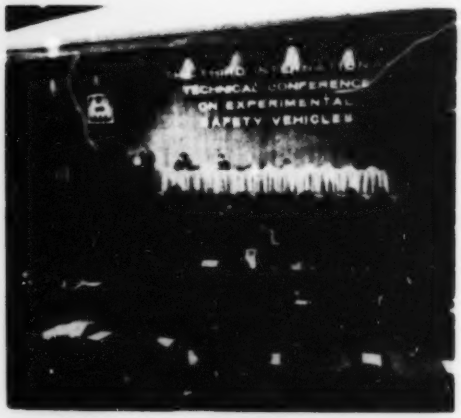
Believing still in the liberal philosophy of progress, we refuse to accept that it will finally end in uniformity. Consequently, not only will the diversity of manners, customs and economic conditions among countries and continents maintain considerable price and weight differences between European and American cars, but such differences will subsist within each market area. Under these conditions, one should look for arrangements tending to respect this diversity which is one of the aspects of free competition for progress and reject everything tending to legalize the law of the strongest, which would result in the contest, between, as the French say, the earthen pot and the iron pot.

Along the same lines, I wish to make a suggestion as regards aggressiveness in lateral impacts, a subject which we previously developed in Stuttgart. The standards are only seeking to increase the lateral strength of the vehicle subjected to impact. Why not also endeavor to decrease the aggressiveness of the impacting vehicle?

An effective method would be to supersede the conventional barrier impact tests by a standard based on the impact of a vehicle of a given type against another vehicle of the same type. The manufacturers would thus be prompted to work on both aspects of the problem in a more realistic fashion than by means of tests which are a poor representation of car against car collisions.

I may have proved to be over-critical in this exposition, but I feel that in such a great democratic country, it will be understood that constructive criticism is more valuable and more cooperative than quiet obedience.

Finally, if Europe, starting later and with less material means, can make a contribution to the safety crusade, it is precisely through profiting by its retard with respect to this country (which, of course, has the merit of taking the initiative) to reflect on the ideas which inspired the immediate action hurriedly undertaken.



THE UNITED KINGDOM TECHNICAL PRESENTATION

SECTION 2 PART 2

"FOREWORD" AND "TOWARDS SAFER ROAD VEHICLES"

RT. HON. JOHN PEYTON, *Minister for Transport Industries*

The United States Government, in initiating the experimental safety vehicle project, took an important step to make the roads safer. I was glad to be able to respond to it on behalf of the British Government. For many years we in Britain have been concerned about road safety; successive governments have consistently tried to reduce the unhappy toll of death and injury. Although the measures taken have had some success — road casualties have not risen appreciably for several years and are proportionately lower than in the United States — we are still far from satisfied. Much has to be done before the roads are as safe as they should and can be.

British road problems naturally have some specific features which are reflected in our approach to car safety. This has three aspects — accident avoidance, occupant protection, and pedestrian safety. We believe that accidents can be avoided if cars have better handling qualities, and equipment which gives drivers more information about their surroundings and what they and others are doing. We want occupants of cars which are involved in accidents to be protected against their effects as far as possible; and, since 40 percent of all fatalities on British roads are pedestrians, we must ensure that vehicles are designed to minimize injuries inflicted on those whom they strike. The British Car Safety Program takes account of all these factors. In it the emphasis is on the development of practical engineering safety systems capable of being incorporated into a wide variety of types of cars.

I am confident that this Third International Experimental Safety Vehicle Conference will show that a promising start has been made in many countries towards achieving our common aims of better and safer roads. The United Kingdom program, which forms part of this major project, is a cooperative venture between government and industry involving substantial funds to develop car safety systems. I am sure that the United Kingdom display in the exhibition will demonstrate that we in Britain are determined to make a real and valuable contribution to this essential international activity.

TOWARDS SAFER ROAD VEHICLES – A STATEMENT ON BRITISH ACTIVITIES

INTRODUCTION

Road safety covers many facets but in research a continuing effort has been devoted in the U.K. for many years to all three main aspects, namely the road environment, the road users, and the vehicle, with the maximum contribution to safety being sought from each. These activities have been supported by the acquisition of traffic and accident data on a comprehensive scale unmatched in any other country. As a result of this work the general level of road safety compares favorably with the best achieved anywhere. In the case of car occupants for example the fatality rate per mile travelled in the U.K. is just over half (55%) that of the U.S. Although this represents a position of some strength there is of course no justification for complacency. For example in the case of youngsters 15 to 20 years old, road accidents account for nearly half of the deaths from all causes. Strenuous efforts are being made to improve the education and training of road users and in particular of the young.

Equally research is proceeding on a broad front to improve the safety of the road environment but it is an inescapable fact that powered vehicles inflict almost all the road deaths and injuries and in this the passenger car is dominant because of its wide usage. It is not surprising therefore that the car occupies most of the interest but motorcycles and heavy load-carrying vehicles must not be neglected. Neither must thought be given only to vehicle occupants, since some 40 percent of road deaths are suffered by pedestrians, the majority of them as a result of being struck by cars.

VEHICLE SAFETY RESEARCH

Two main choices are available in designing a comprehensive program of vehicle safety research. One approach is to pursue the development of complete vehicles to much higher levels of safety than are achieved by their present-day counterparts. An alternative approach, which may be more fruitful when a wide range of vehicles is involved, is to direct research to establishing general performance levels and to identifying selected vehicle features which promise worthwhile improvements in safety. Within this framework research may be conveniently divided into two categories. One is accident avoidance, and the other protection of people during or following a collision, whether they are vehicle users or pedestrians.

ACCIDENT AVOIDANCE

In considering accident avoidance we must not restrict ourselves only to measures which prevent a dangerous situation developing into a collision; we must also find ways of minimizing the onset of dangerous situations. In the latter category are devices intended to help road users to take the correct decisions and to warn drivers of the dangers ahead; two current examples are the head-up displays of speed and of minimum safe following distance, and the RITA system of aural communications with drivers.

Non-Locking Brakes

A highly desirable requirement of accident avoidance is that a driver should be able to maintain complete control of the vehicle while braking and maneuvering in emergencies, even under adverse road conditions. The ability to do so is critically dependent upon preventing wheel locking and this applies to all three main categories of vehicles: motorcycles, passenger cars and goods vehicles. In the case of articulated vehicles wheel locking can lead to jackknifing, or to trailer swing; the former is virtually uncontrollable once started, the latter too is very dangerous because the driver may be unaware that it is happening. Considerable technical progress has been made on non-locking braking systems for all three classes of vehicle but the establishment of an economically viable requirement is dependent upon the accident savings which can be achieved by non-locking braking systems, bearing in mind that various system options exist with a corresponding range of costs.

Following a large scale trial of anti-lock devices on articulated goods vehicles the U.K. is planning to carry out a trial of current production cars equipped with non-locking brakes. To obtain a reliable answer within a reasonable time the trial will need to be mounted on a large scale and will depend for success on the cooperation of many people and organizations. However, if carried through it will represent a major initiative on the part of the U.K. toward establishing a case for or against the adoption of non-locking braking systems for cars.

Handling Qualities

Another important aspect of collision avoidance is the influence on it of that rather abstract quality known as "handling." A large amount of work has been carried out on the subject mainly from the standpoint of customer acceptance but there is at present very little information relating handling features or performance levels of handling to accident involvement.

PROTECTION AGAINST INJURY

Accident reduction is of course the most desirable target because it brings with it the dual benefits of savings in both injury and property damage. But it would be indefensible to neglect measures which offer worthwhile reductions in personal injuries when a collision or loss of control occurs. This subject is not as straightforward as might appear at first sight because a gain in safety for the people within a car might accrue at the expense of increased injury to occupants of other vehicles or to pedestrians. Furthermore it by no means follows that a demand for survival at very high impact speeds will yield the best solution because most injuries and collisions occur at modest speeds. Much more is likely to be heard of these aspects as car safety programs evolve.

Human Tolerance

In pursuing greater occupant protection there are two outstanding problems neither of which is new. The first concerns the need for more data on human tolerance, i.e. the ability of the body to withstand without serious or permanent injury, unusual loads over brief periods of time; it is essential for the data to relate directly to the variety of events that occur in actual accidents. This information is crucial to vehicle design and from this standpoint one can readily appreciate the need for occupant protection to be regarded not simply as an add-on system but as an integrated vehicle design problem involving both the basic structure, the interior design and the occupant restraint system.

Test Techniques and Occupant Restraint

The second problem concerns test techniques for type approval and quality control, two of the most important being the representation of the human occupant and the associated performance levels to be applied. Both of these reinforce the need for an overall performance standard for occupant protection rather than an accumulation of piecemeal design requirements. A basic issue in forming a standard is the assumption to be made regarding the use of occupant restraints. The value in injury savings from the regular use of seat belts has been amply demonstrated but the majority of car occupants do not use them at the present time even though most cars are now equipped for the front seating positions.

To cover both situations, i.e. restrained and unrestrained occupants to the same level of protection would impose very great design problems. It is the U.K. view therefore that an occupant protection standard should be based primarily on the assumption that restraint systems will be used but it should make some provision for the unrestrained case; the survival levels for the latter however will almost inevitably be substantially below those for restrained occupants.

VEHICLE REGULATIONS

The research towards safer vehicles will be of value only when the results have been embodied in production cars. Close collaboration has existed between industry and the U.K. government for many years and many of the lessons learned have on the initiative of industry been embodied in production vehicles almost unnoticed by the general public. Nevertheless there are many instances when it is desirable and sometimes essential to reinforce the situation by official regulations.

Vehicle regulations in the U.K. are a government activity with a history nearly as long as that of the motor car itself. The first regulations were in force before the turn of the century, and since then refinements and additions have followed in a continuous stream. The primary objective has been the promotion of the safety and welfare of the citizen, as driver, passenger and as bystander. To a large extent these regulations have traditionally taken what was best, or at least what was a desirable minimum, out of current practice and technology and laid it down as a standard for all to observe.

In recent years most people have become increasingly aware of a second strand in vehicle regulations. Safety considerations have inspired many countries to develop systems of regulation comparable to our own – comparable but not identical. The development of a vast international trade in motor vehicles has made it abundantly clear that compliance with the multifarious requirements of the many export markets is a major headache to the manufacturer. The demands of safety cannot be disregarded but in many instances the differences do not represent different degrees of safety. They exist simply because administrators have approached the same problem in isolation from each other and have tackled it in their own way, with the frequent result of provisions of similar effect but annoyingly divergent in detail.

From this situation spring the efforts, particularly through the agency of the Economic Commission for Europe, to develop internationally agreed regulations. Valuable work has been done although progress is admittedly not as fast as either the industry or the Department would like. An impetus to this search for harmonization has been given by the efforts of the Common Market. As a part of the Community's program of work to eliminate barriers to trade between member states a system of standards is being developed and embodied in directives within the framework of the EEC type approval system. When this system is complete any vehicle which conforms to all the standards must be accepted throughout the Market area. British membership will enable us to benefit from this system.

Another comparatively recent development in the field of vehicle safety is the tendency for governments to go beyond the traditional role of merely consolidating existing good practice. The increasing toll of road accidents and the mounting concern in all quarters – public opinion, press, parliament and government – to explore all possible means of curbing it have inevitably focussed attention on a number of areas in which a more positive approach might appear to pay dividends. Amongst these naturally figures the setting of new requirements for the design and construction of vehicles intended to achieve new levels of safety for road users.

In the future this more active role of government seems likely to develop. Although the industry continues to devote spontaneously much effort to the improvement of vehicle safety, and although what the industry can technically achieve sets a limit to what can be required by regulation at any given time, it is nevertheless true that government initiatives may promote the concentration of resources in such a way that desirable improvements are achieved more quickly than would otherwise be the case.

One method of setting about this would be to link regulations not to what is now technically possible but to what is hoped to be possible in the future — to set a kind of legal target which the industry must achieve by a stated date. This is not however the U.K. approach, where it is considered preferable to foster the necessary research and development in order to demonstrate the practicality of a new requirement and also to show that its introduction could be expected to produce benefits in terms of accident or injury reduction commensurate with the cost it would impose on the public.

It is important too that standards should not be drafted in such a way as to inhibit further development and innovation by the industry. For this reason the U.K. will be looking increasingly towards performance-based standards rather than design-based standards. By this is meant that a standard should ideally tell the manufacturer how the vehicle should behave in certain prescribed conditions, rather than prescribe the constructional features which must be incorporated to make it behave in such and such a way. The manufacturer then retains the freedom to develop and modify design in such a way as to achieve the required performance standard more efficiently.

A particular field in which we are interested in developing such an approach is that of occupant protection. Regulatory action in that field recognizes that accidents will continue to happen, whatever other improvements are made in vehicle design, in road layout and in driver behavior, and sets out to mitigate the consequences of this inevitable residue of accidents to the driver and passengers. The U.K. believes that the principle is good, and is interested in investigating, in co-operation with the industry and with other governments, the way in which it might usefully be applied to the typical European car. It may well turn out that this will be the most satisfactory way of implementing the lessons which will be learned from our research program as to the feasibility of new levels of vehicle safety.

DRIVING AIDS

MR. H. A. J. PRENTICE, *Head of Driver Aids and Abilities Division*

Transport and Road Research Laboratory

INTRODUCTION

Over the last 25 years the average speed of vehicles has considerably increased, the traffic density has greatly increased, as has the number of regulations, signs and signals which must be obeyed or interpreted. In addition development in road layout design has not solved all the problems facing the driver in reaching his decisions. The physical and mental abilities of people who must operate in this environment have not changed. The problem then is to ensure that people drive within their physical limitations and yet drive to a higher standard of safety than at present. Here we are not dealing with a specialist body like air-line pilots but with an entire cross-section of the population. It is therefore necessary to either provide drivers with instruments to make up their deficiencies or to take the decision-making out of their hands. This can be done either by altering the structure of the environment or by providing suitable electro-mechanical equipment. Automatic systems now available are far superior to man in the speed with which they can make decisions and can thus be used to supplement the driver in critical driving situations.

The limitations of human performance are under continuous study at the Transport and Road Research Laboratory, so that the appropriate equipment may be developed.

The TRRL in looking at these problems has concentrated on a limited number of items, details of which are available in this paper, or in the exhibition at Dulles. In the area of helping the driver by giving him the right information in the right place the Head Up Display speedometer has been demonstrated to be a very valuable aid and can now be produced at an economical cost. Using the same principle a station keeping indicator is being developed that will advise drivers on the minimum safe following distance from the car in front. The whole concept of aural communication is being looked at and plans are being developed for systems specific to individual drivers. The night driving problem is under continuous study and recent work on vehicles has been on a "dim-dip" or running lights system. Finally the "dual-mode" vehicle has been considered as the ultimate form of personal transport; working on this project has yielded a technological spin-off in the sense that we can now see safe ways of remotely controlling speed and braking of vehicles. As part of this project an automatic following system giving close, high speed following in safety is being developed; the broad outline of this work together with proposed ways in which the various steps in reaching full automation might be implemented are given later.

VEHICLE BORNE DISPLAYS

Station Keeping Indicator

A safe time interval between vehicles may be regarded as being one within which the driver of the following vehicle is able to react to the stopping maneuver of the preceding vehicle and initiate his own stopping action, in other words his brake reaction time. Therefore, if a driver travels behind another at such a distance that he is able to react before his vehicle passes the place on the road at which the preceding driver reacted and his vehicle does not have an inferior braking system, he should always be able to stop safely when only braking is involved. Under the most favorable conditions, that is, in a simulated emergency, brake reaction times of less than half a second are not unusual. However, in a true emergency situation with an alert but unexpected driver a reaction time of less than one second is unlikely. On one fully instrumented section of urban motorway in the United Kingdom time intervals between succeeding vehicles of less than one second are regularly recorded. There is no reason to suppose that this finding is other than typical of all heavily trafficked fast urban roads.

The problem is that it is virtually impossible for a driver to be able to choose unaided correct following distances for particular speeds so as to always allow for a one second minimum reaction time.

As an aid to achieving greater safety in car following situations a device has been developed at TRRL which may be used to indicate to the driver the minimum following distance at which he should travel to allow himself one second in which to react.

This device comprises a pair of vertical lines against which the vehicle being followed is viewed by the driver. The gap between the lines is varied by the speedometer mechanism so that the faster the vehicle travels the closer the lines move together. It is essential that the driver sees the lines at the same time as he views the vehicle ahead. When the vehicle ahead is bracketed by the lines he is then at a safe following distance. This is achieved by the use of a head up display system similar to that used in combat aircraft or, in a modified form, to display speedometer readings in motor vehicles, as exhibited at Dulles.

The optical components used are quite simple. A cheap plastic moulded lens of aspherical form is used as a collimator. This lens is used to produce images of the lines which are seen by the driver as reflections in his windscreen. The reflection actually comes from a small flattened area of the windscreen. The production of such a flattened area is not as difficult as it would at first seem to be since on modern cars the portion of the windscreen normally viewed through when looking straight ahead is very nearly flat. The lines themselves are generated by means of a single strip filament lamp which is moved by means of a drive taken from the speedometer mechanism. Two lines are obtained by using a view of the lamp directly together with its real image formed by means of a small concave mirror.

In practice the device has been so calibrated that it may be used when following most passenger cars on British roads with an error of approximately ±10% taking the widest and narrowest vehicles. It may also be used with trucks, etc., since they are required to have rear end markings of certain sizes which could be used in lieu of the overall vehicle width. These marking sizes are not yet tightly controlled but the appropriate legislation exists to do this if necessary.

Brake Lights

To be more certain of safe stopping even though he has been able to react within one second a driver needs to know as quickly as possible that the vehicle ahead has initiated emergency braking. At present there is no way of knowing how severely the driver ahead intends to stop. A system which will indicate the severity of braking as well as its onset is being developed. It takes the form of a multi-level brake light display. Simply, the greater the vehicle deceleration the more brake lights are illuminated. At present three separate levels of deceleration are used and up to seven lights are used illuminated in the sequence one, three and seven lights as the deceleration severity increases giving an impression of suddenly increased vehicle width.

IMPROVEMENTS IN VEHICLE LIGHTING SYSTEMS

Driving at night poses its own particular problems and the present systems of vehicle lighting in general use throughout the world are the result of an evolutionary process that has gradually been taking place since it was found that the primitive lighting carried by the first mechanically propelled vehicles was not good enough to fulfil the functions of enabling a driver to see where he was going, and to warn other road users of his presence and intentions. In particular, the headlamp in its present form is a searchlight that will enable a driver to see as far ahead as possible without causing intolerable glare to drivers of vehicles approaching from the opposite direction. Thus the headlamp must be a compromise and like most compromises the end product is not entirely satisfactory. Visibility given by the upper beam is adequate in most cases but this is not the case with lower beams, which also still give undesirably high glare illuminances in the direction of oncoming drivers, in spite of modifications in the distribution of the light emitted by the lower beam. It is felt that the present headlamp systems have now been developed as far as they can go and that any improvement will only be achieved by the use of entirely novel systems. The idea of polarized light headlamp systems has been with us for a long time and there is much current activity both in Europe and the U.S., where the results of proposed tests are awaited with interest. Looking further ahead we can imagine the general use of "opposing driver sensitive" headlamp beams that will automatically avoid emitting any light in the direction of an oncoming driver's eyes.

For the immediate future, however, we shall have to exist with the present system of upper and lower headlamp beams and the main task, from the point of view of the safety vehicle, is to ensure that the lower beam is used as safely and effectively as possible.

The full benefit of the present design of headlamp beam is only obtained when it is correctly aimed and it is obviously desirable that this correct aim should be maintained at all times. Headlamp aim is normally carried out with the vehicle unloaded except for the driver. Unfortunately many modern vehicles tilt to a significant extent when loaded and measurements in Britain have shown that the tilt is more likely to result in a 'nose up' attitude rather than the reverse. A change of only 1 degree upwards in vehicle attitude can result in severe glare to an oncoming driver, even with headlamps that have been correctly aimed. In seeking a low cost solution one approach to this problem has been tackled in Europe. It has been to pivot the headlamps in their mountings then making them automatically tilt to compensate for vehicle body movements. This has been achieved by means of either hydraulic or mechanical systems, the latter being the cheaper. Both systems use the relative movement of wheel axles and car body to produce the necessary correction signals. The front and rear suspension movements are detected and are combined to transmit a vertical angle correction system to the pivoting headlamps. Both the hydraulic and mechanical systems have been tested statically and dynamically. A load of 500 lb in the rear of the cars tested caused a 'nose-up' attitude of approximately 1.25 degrees but the compensated lamps in both systems moved by less than 0.1 degrees from the horizontal.

The lower headlamp beam is designed to allow drivers to see ahead as well as possible in the face of oncoming traffic. On unlit and poorly lit roads it is imperative that the lower beam should emit as much light as possible, as long as the light emitted in the direction of an oncoming driver's eyes is kept within reasonable limits. However, more and more roads are nowadays being equipped with street lighting of a much higher standard than in the past, and the need for lower beams to emit light at their full intensity no longer exists, although there must be some form of vehicle lighting to permit pedestrians and other road users to differentiate between parked and moving vehicles. Although some countries adopt the practice of using normal lower headlamp beams at all times, whatever the standard of the street lighting, in others, such as France, lower headlamp beams are not normally used in areas where the street lighting is good. In Britain practice varies between one town and another, but the use of standard lower beams in well-lit streets has been shown to be a disbenefit in terms of accidents.

It would be desirable to have some form of intermediate front vehicle lighting lying between the normal parking lights and the normal lower headlamp beam and such a system has been developed. This system automatically reduces the intensity of the lower headlamp beam when a vehicle is in a well-lit area until the brightness of the headlamp is about 20 per cent of its normal value. This is bright enough to enable the light to be differentiated from a parking light.

The automatic headlamp brightness control has to meet a number of different requirements for satisfactory operation. Firstly, it must be sensitive to light from the street lighting luminaires but not to light from the headlamps of opposing vehicles. This is achieved by taking advantage of the fact that as headlamps are normally run from a direct current supply they give a steady output whereas the light from the discharge sources normally associated with high quality street lighting installations fluctuate at a frequency that is twice that of the electricity supply (i.e. at 100 Hz in most of Europe and at 120 Hz in the USA). Although fluctuations at these frequencies cannot be detected by the human eye they can be easily detected and amplified electronically. This is what the control device does.

The second important requirement is that the device should not be sensitive to isolated light sources but should wait until light of the required intensity has been continuously experienced for a long enough period (typically 25 seconds) to ensure that the vehicle is in fact in a well-lit area of some extent. Thirdly, it is imperative that the headlamp beam should revert to its full brightness on leaving a well-lit area for one without street lighting, or with street lighting of a lower standard. Both these requirements are satisfied electronically.

AURAL COMMUNICATION

Both from the point of view of road safety and traffic control it is recognized generally that the communication link with the driver must be improved. At present the driver uses his visual senses to control the path of his vehicle and simultaneously to seek relevant traffic and safety information from visual road signs. In spite of improvements in visual signing and visibility from vehicles the driver's visual senses are heavily loaded in many driving situations and this position will deteriorate further as vehicle densities increase. It is also a fact that visual signs are frequently obscured for a variety of reasons (e.g. other traffic, difficult siting problems, heavy rain, fog, snow etc.). Serious consideration has been given therefore to the communication of information to drivers by means of the aural sense.

Two kinds of information are required by drivers – one is strategic and the other is tactical. Strategic information is used by drivers to plan their journeys, ideally before starting out on the road system; this is best provided by the present traffic information services radiated by local radio stations or national broadcasting networks. Such information is regionally based and gives a general picture of the situation in the road network. The second kind of information required is tactical i.e. that required for detailed traffic control and emergencies on individual roads within the network and it is this kind of information with which the TRRL RITA (Road Information Transmitted Aurally) project is concerned. The tactical information is under the immediate control of Area Traffic Control authorities and provides the communication channel for traffic control measures.

It is necessary for operational reasons, apart from driver convenience, that information be confined to a particular carriageway i.e. so that drivers will only receive messages relevant to their carriageway and direction of travel, as in present visual methods of traffic control. This requirement limits the choice of techniques available for a RITA system.

A range of standard messages appropriate to the particular location would be pre-recorded and stored in a message bank; the messages would contain information relating to traffic control measures (diversion, tidal working, lane closures, speed) and emergency situations (accidents, weather conditions). The message bank can be located at the roadside transmitting point or in a central control room from which the traffic controller can select the appropriate message for the location and traffic situation.

When the roadside transmitter is not required for its traffic control or safety function the messages radiated can provide route and amenity information. Since drivers familiar with the area would not require this information they could switch off their message receiver. However, when traffic control or emergency messages are transmitted all receivers would be switched on automatically by suitable coding tones on the roadside transmitter.

With such a communication channel available in the vehicle it could be used for other situations such as directions to car parks, transit areas, advice on all-night restaurants and garages, thus providing a very valuable amenity service. In addition to the permanent roadside installation portable equipment would allow temporary traffic control for large public events and police requirements.

Research at TRRL has been concerned with three main aspects; the question of driver acceptance, the division of attention between aural and visual inputs to the brain, and the evaluation of possible technical systems.

Driver acceptance of a simulated installation has been found to be very favorable in trials in Central London both by day and night. Experiments on the division of attention show no drop in driver performance, and on the whole drivers were more relaxed and gave more attention to their driving.

In technical systems considerable experience has been gained with buried loop techniques. Problems have been encountered at bridges and on reinforced concrete structures; in general however, the system is satisfactory. The frequencies are confined to below 500 kHz. and there is the problem of the disturbance to traffic during installation.

The use of point source radio transmitters with a triggering system is very attractive but in the United Kingdom there is the very difficult question of frequency allocation in an already overloaded spectrum.

Investigation is going ahead into the newer near-field systems such as a leaky coaxial cable, and a short buried loop employing "fast in – slow out" methods using digital techniques would enable a lengthy message to be passed to the vehicle in milli-seconds, and then played back slowly aurally to the driver. This method has the advantage that the information could be held in store for repeating if necessary.

Full scale road trials are planned for the RITA system and pilot installations are being evaluated.

DUAL MODE VEHICLES

So far the work described has been research into how drivers carry out their task of controlling vehicles, and into methods of helping them in this task. However, there are distinct limitations to a human being's performance as a controller, particularly with the present day, regular increases in traffic speeds and densities. Therefore a more radical solution is now being worked on which replaces rather than merely aids the human driver. This will be achieved by converting normal road vehicles to dual mode operation by fitting them with electronic "autodrivers" similar in concept to aircraft autopilots. The idea is that people will drive as usual on minor roads, but will switch to the automatic mode on main roads and motorways.

The first question arising from this concept of highway automation is "why," and the only satisfactory answer to it, as with any proposed technological advance, must be because the economic and social benefits from highway automation will exceed its costs. The main quantifiable benefits expected are

1. reduced number of accidents, because of the much higher reliabilities obtainable from machines than from human beings, and
2. increased road capacities, due to more accurate steering, quicker reactions, i.e. more vehicles per unit length and better control at junctions.

It should be remembered that if main road automation were complete, manual driving (and the accidents arising from it) would be confined to minor roads where slow speeds could be enforced. The need for expensive safety devices required to protect occupants in high speed accidents will then disappear and the cost of these can be offset against the autopilot costs. A simple cost/benefit analysis has suggested that these benefits would justify an equipment cost of up to £5000/lane mile and £75 - £100 per vehicle. Automation would appear to be justifiable provided its cost is of this order and present effort is concentrated on finding out if reliable systems can be produced in this price range.

The present position at TRRL is that there are two cars (a Mini, the smallest British car and a Cortina, a medium-sized saloon) able to steer themselves automatically using a single leader cable system, and able to respond to speed, stopping and starting commands received by inductive links from the road. These vehicles use simple and cheap control actuators electric motors for steering and electro-vacuum systems for throttle and brake. Work has just started to convert a bus to automatic control; this will carry a general purpose analog computer for control system tests and mathematical modelling work.

The main technical problem which workers in this field are trying to solve is that of automatic longitudinal control, to allow both close following of other cars and stopping at obstacles in the road. Two approaches seem promising here:

1. a self-contained or "non-co-operative" headway measuring system such as primary radar
2. a "co-operative" system using electronic equipment in the vehicle to be followed as well as in the following vehicle.

At present it appears that a non-co-operative system will only allow safe following at headways down to 1-2 seconds, i.e. rather longer than those used by human drivers. This would not increase road capacity, and to achieve much shorter headways than used by human drivers a co-operative system would appear to be essential, either secondary radar or a system indicating position measurement with respect to inert road markers and a microwave link to following vehicles.

Investigation of possible techniques during the past two years has indicated that such a system is technically possible. The need for co-operation however increases the difficulties of introducing automation onto a country's main road network. Since this introduction problem is important it is discussed in detail below.

It is felt that the chances of introducing a program of vehicle automation in most countries will be very small if it involves either legislation forcing drivers to fit equipment to all vehicles, or building special new roads for automatic vehicles. A gradual introduction program is favored at present with the aim that each stage must be economically viable and socially attractive in itself while leading both technology and public opinion towards the next stage and eventual full automation. It should be noted that automatic vehicles are already in use, such as driverless factory tractors, vehicles in mines and tunnels, farm tractors, vehicles for tire and automotive component testing. Such a phased program could be as follows:

1. Automation of buses operating on reserved tracks, such as the bus way already in use at the New Town of Runcorn. This should reduce labor costs and allow a much improved late-night service, and should also allow the buses to be run more economically. This could be regarded as a "horizontal elevator," a great advantage being that since the vehicles are normally driveable, they could be used off the reserved track, which considerably improves their economic use.
2. The use of road-to-car communication links; e.g. in-car displays of road signs passed, route guidance, control of speed and braking.
3. The introduction of a co-operative headway control system giving very close following at high speeds. This would require reservation of the offside (or right hand) lanes of motorways for equipped vehicles. Initially steering would be carried out by the driver, while the automatic system handled only longitudinal control, followed by reserving the nearside (or left hand) lanes for commercial vehicles.
4. Conversion of these reserved motorway lanes to full automation, including steering.
5. Extension of reserved lanes to all main roads.

Technically the problems involved are soluble, and the governing factors in implementation will be politico/economic rather than technological.

CONCLUDING NOTE

Modern life requires safe efficient transport, there is no substitute in sight for the road vehicle, and human beings' abilities as control systems are severely limited. With the present very rapid developments in electronics and technology generally, the urgent need to make better use of existing roads, the rapidly growing vehicle population and the need to cut the economic cost of accidents it is anticipated that devices leading ultimately to reserved automated lanes will be in common use before the end of the century.

VEHICLE HANDLING

MR. GILL JONES, *Chief Vehicle Safety Engineer*

British Leyland Motor Corporation

INTRODUCTION

From a broad consideration of all the available information and from our own accident investigations it is evident that avoidance of accidents is no less a priority than occupant protection and that the handling and stability of vehicles is a subject of great importance.

The technical background dealing with vehicle stability is such that informed engineers have a good appreciation of the important factors involved. Within the scope of vehicle handling there are many factors which the designer has to consider such as side wind stability, traction under poor grip conditions, stability under braking and vehicle ride.

Some of the requirements tend to be conflicting and so the design as always is a matter of selection and compromise.

In establishing minimum standards which have a realistic relationship to safety and which are readily applied during the design and development process a clear analysis of the available information is necessary. It would be of great benefit to have clear objective evidence of required performance levels based on accident investigations but inevitably the interaction of a number of factors involved in each individual accident makes it difficult to establish this.

Investigations are however being carried out to try and relate accidents to handling characteristics.

Experience of vehicles having either oversteered or understeered prior to accidents has been sufficient to emphasize the basic importance of these effects relative to safety.

Steady State Response

Many people nowadays have a broad understanding of oversteer and understeer but for those who are least familiar with the subject we may briefly say that oversteer is a condition in which the rear of a vehicle tends to drift outwards away from the point about which it is turning and so requires the steering wheel to be turned opposite to its normal direction or to an angle which is less than the simple geometric or Ackermann requirement. Understeer is a condition in which the front of a vehicle tends to drift outwards and so requires the steering wheel to be turned to an angle which is greater than the simple geometric requirement.

FIGURE 1 illustrates a vehicle following a curved path in accordance with Ackermann layout and from this we can see what is meant by yaw velocity, a term used regularly in vehicle handling and stability presentations.

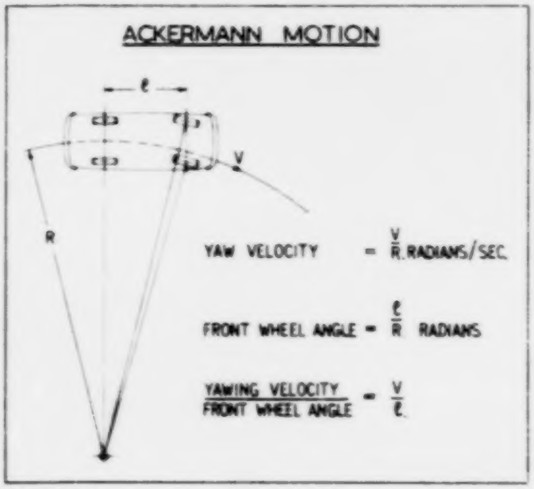

ACKERMANN MOTION
ℓ
V
R
YAW VELOCITY = V/R RADIANS/SEC
FRONT WHEEL ANGLE = ℓ/R RADIANS
YAWING VELOCITY / FRONT WHEEL ANGLE = V/ℓ

FIGURE 1

FIGURE 2 shows the United States specification for steady state response, the phase 1 proposals being superseded by a requirement for more understeer in accordance with recommendations by the Digitek Corporation. By relating the proposed acceptable range to the Ackermann line for a vehicle of 116 inch wheelbase it will be noted that the final specification requires a large amount of understeer. For a typical

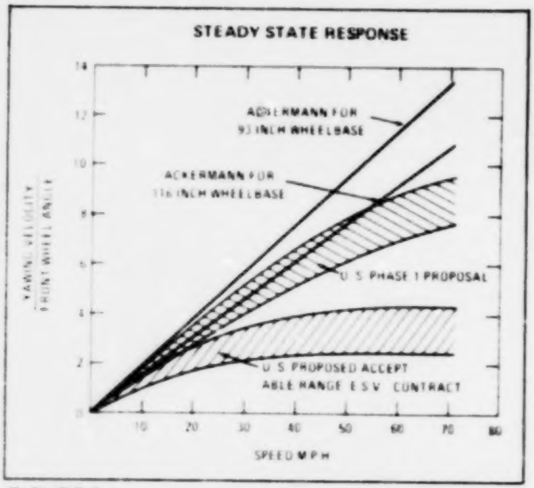


FIGURE 2

European vehicle of much shorter wheelbase the amount of understeer is even greater and there is obviously a necessity to relate the requirements to the wheelbase. From an analysis of information on smaller vehicles of the European type the indications are that the upper limit of acceptability for such vehicles may well be within the phase 1 U.S. specification.

Although the acceptable range relates to a lateral acceleration of 0.4 g the U.S. specification includes requirements which ensure that as the g value and speed increases the trend must be towards increased understeer. While such requirements are necessary this specification itself does not cover the range of desirable steady state characteristics.

FIGURE 3 illustrates the difference between front and rear wheel slip angles plotted against lateral acceleration, these results representing a measure of the change in understeer as the acceleration increases and being obtained from a tethered test.

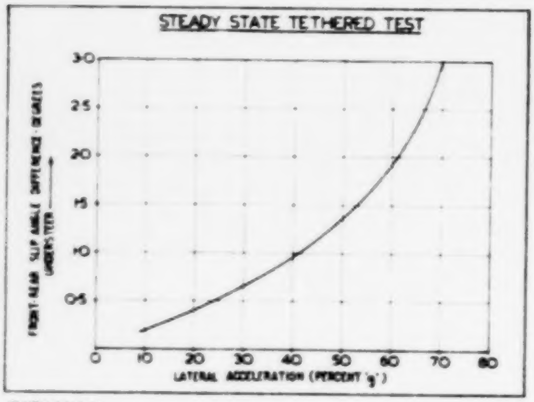


FIGURE 3

Response results plotted against acceleration are very useful in the development stage and may be useful in determining acceptance levels.

Curves of the form shown in FIGURE 3 are obtained from tethered tests carried out at the Motor Industry Research Association. The test vehicle is attached to a mobile anchor vehicle at any required attitude and, if necessary, with traction or braking forces applied through the road wheels in the normal way. The necessary data recording apparatus is carried within the anchor vehicle.

Transient Response

The basic oversteer/understeer characteristics are equally applicable to the response from transient steering action as in a rapid lane change or other such maneuver, in which loss of control can occur in a fraction of a second. In determining the specification most suitable for accident avoidance in such maneuvers we believe that studies should include the performance capability of drivers relative to vehicle response.

FIGURE 4 shows the response from a vehicle of 96 inch wheelbase following a step steer input in accordance with the United States ESV specification.

It will be seen that in the 25 mph test the vehicle fails to meet the requirements for initial response and in the 70 mph test it fails to be within the envelope beyond 1.6 seconds.

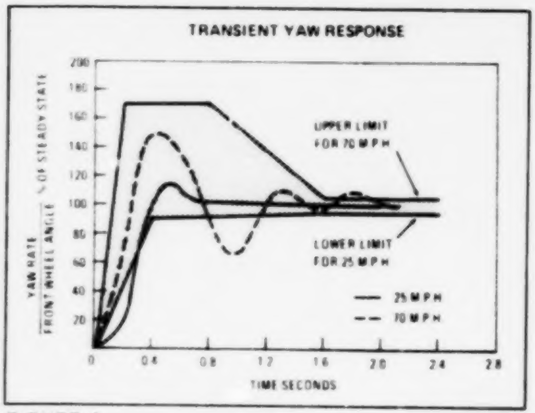


FIGURE 4

The requirements in these areas appear to be unnecessarily restrictive and can be expected to have negligible effect in enhancing the safety of the vehicle.

In particular at 25 mph where a large steering input is necessary, the required steering angle is not reached until a time of approximately 0.3 to 0.4

seconds has elapsed. The yaw rate must initially have a zero value and the slope of yaw rate against time initially must also be zero. Hence it is difficult to see a practical vehicle responding sufficiently rapidly to remain within the 25 mph envelope during the initial fractions of a second.

FIGURE 5 shows a comparison of recordings from a rapid lane change maneuver with a small vehicle in normal trim, and with tire pressures drastically changed to oversteer. In the changed condition the performance was subjectively quite unacceptable.

The effect which tends to result in loss of control and which is illustrated here, is the time lag between steering movement and response. Such lag is contrary to simple human expectations since in normal driving the response is reasonably coincidental with input.

Neither of the cases in FIGURE 5 refer to normal driving but it will be noted that after 0.8 seconds from the start of the maneuver the oversteer car is just changing direction of yaw whereas the normal car is yawing appreciably to the desired parallel path in the overtaking lane.

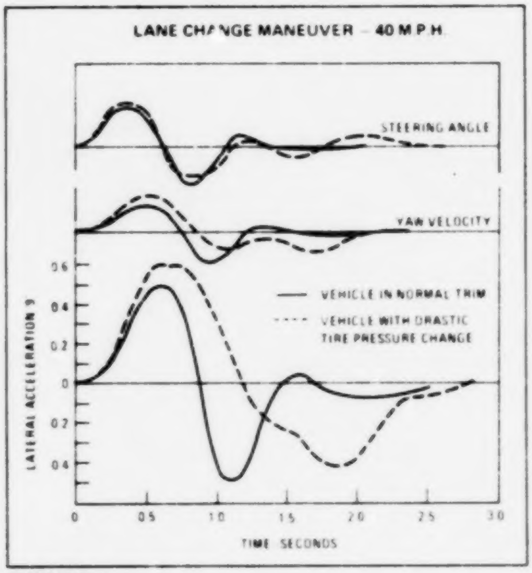


FIGURE 5

As a result of the difference in yaw, and as shown by the lateral acceleration curves, the oversteer car was still turning across the lanes almost half a second after reaching full reverse steering movement. The vehicle crossed over to what could have been the path of traffic travelling in the opposite direction.

Time Lag as Explained by the Fundamental Dynamic System of a Motor Vehicle

Time lag between input and response is a fundamental characteristic of spring/mass systems and is dependent upon the ratio of the input frequency to the natural frequency.

It is also modified according to the degree of damping.

FIGURE 6 shows frequency response measurements from a typical small European vehicle at a speed of 50 mph, these being extracts from research carried out by the Motor Industry Research Association. The response amplitudes at the particular test speed are representative of a well-damped mechanical vibration system and the response lag follows the theoretical pattern except at high frequencies where interaction between the hand wheel and the road wheels is considered to be the cause of the difference.

The peak yaw response amplitude occurs at 0.6 cycles per second and this represents the natural yaw frequency.

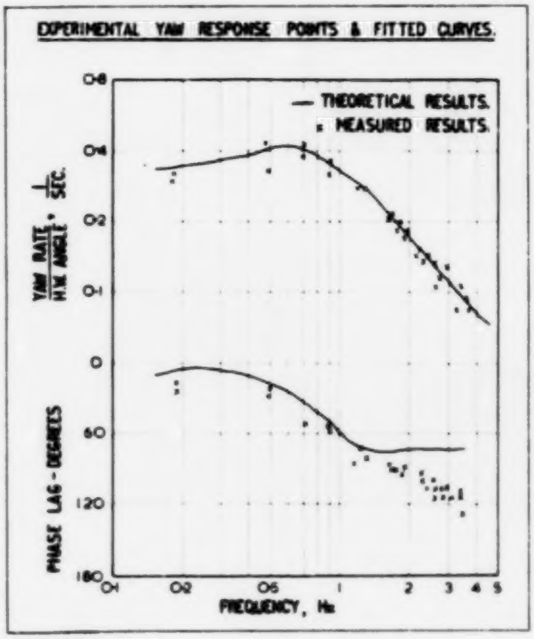


FIGURE 6

Implications from Theory and Practice

The implications from consideration of transient response effects are that maximum driver control is obtained when the natural frequency of yaw is highest and when optimum cornering power is obtained by having a suitable amount of understeer. High yaw natural frequencies are obtained by the use of tires having a high lateral stiffness acting over a long wheelbase and by keeping the yaw inertia of the vehicle to a minimum.

Since, with large vehicles in particular, an increase in wheelbase introduces problems associated with steering ratio, it is probable that the most fruitful means of obtaining a quicker response and reducing time lag is by inceased tire lateral stiffness. More research is evidently required to relate these basic characteristics to driver behavior in emergency maneuvers before a true safety related specification for transient response can be formulated.

ESV developments for occupant crash protection can, as illustrated in FIGURE 7, be incompatible with the requirements for improved handling and so the factors considered in this paper need to be taken into account in the overall assessment of a true Experimental Safety Vehicle.

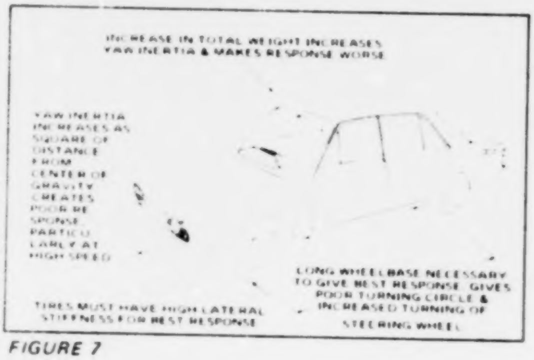

INCREASE IN TOTAL WEIGHT INCREASES YAW INERTIA & MAKES RESPONSE WORSE
YAW INERTIA INCREASES AS SQUARE OF DISTANCE FROM CENTER OF GRAVITY CREATES POOR RESPONSE PARTICULARLY AT HIGH SPEED
LONG WHEELBASE NECESSARY TO GIVE BEST RESPONSE. GIVES POOR TURNING CIRCLE & INCREASED TURNING OF STEERING WHEEL
TIRES MUST HAVE HIGH LATERAL STIFFNESS FOR BEST RESPONSE

FIGURE 7

Practical Handling Tests

For many years manufacturers have used skid pad and chicane tests to assess handling. The chicane test simulates a violent swerve to avoid an obstacle and vehicles completing the maneuver in the shortest period of time have been rated as the best. Progress during development of a vehicle has to a large extent been based on these results.

Chicane test comparisons do of course have to be judged on the basis of a standard driver being used and there is inevitably an unrealistic element when such a driver is experienced in performing the task and can make steering corrections which normal drivers would never experience except in an emergency.

Tests on a curve at increasing values of lateral acceleration are also included in routine development and these sometimes reveal effects from interference with front to rear stiffness ratio caused by suspension travel limit or bump stops. Cornering capacity and breakaway characteristics are also assessed on surfaces having low friction coefficients. From all these tests the degree of understeer is established.

CONCLUSIONS

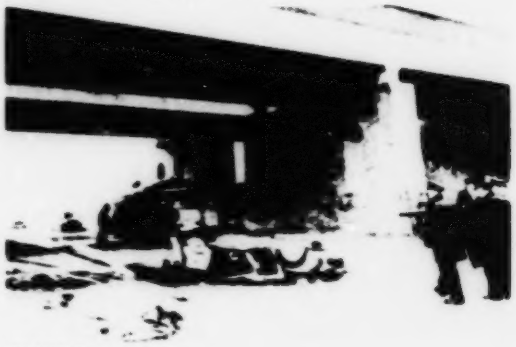
Steady state and transient response has been the main topic for discussion in this paper because these are thought to be of primary importance and the basis for a broader scope involving traction and braking, and involving behavior on surfaces having low friction coefficients.

In the considerations on transient response it is felt that driver reaction to the response from an initial transient input can reveal characteristics which are more representative of real conditions. The examples given may be of use in presenting these views.

THE TOTAL MOBILITY TIRE

MR. HARRY KEEN, *Manager*
North American Tire Development Group
Dunlop Tire and Rubber Corporation

Analysis of recent accident data in U.K. has shown that many accidents causing personal injury were preceded by tire deflation or failure in one of the vehicles. This allied to the fact that nails or nail-like objects will always penetrate tires – irrespective of their construction – has led to the development of The Total Mobility Tire which is fitted to both of the British vehicles at the Exhibition (slide 1).



SLIDE 1

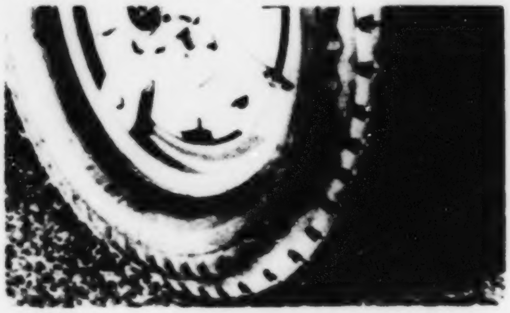
Not only is the deflation of a conventional tire dangerous in itself; it reduces vehicle mobility effectively to zero and the fitment of the spare wheel can be hazardous in its own right (slide 2).

SLIDE 2

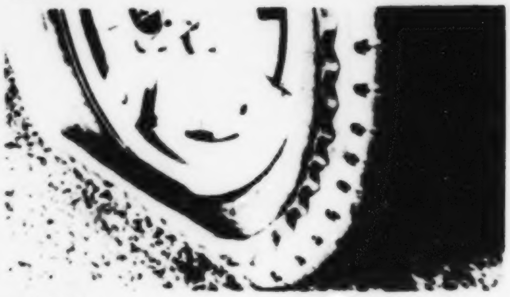
THE
'TOTAL MOBILITY'
TYRE

SLIDE 3

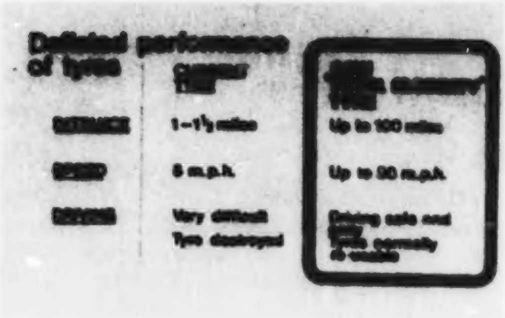
An increasing percentage of motorists (particularly women drivers) are incapable of changing a spare wheel. The Total Mobility Tire is actually *designed* to run with air and without air (slides 3, 4, and 5).



SLIDE 4



SLIDE 5

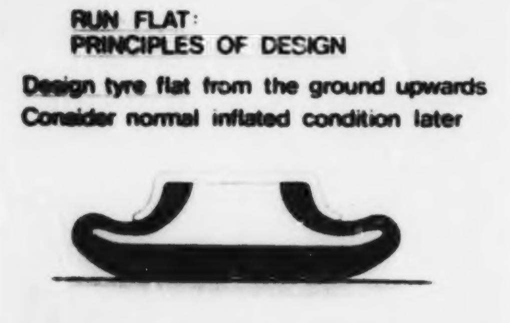


Deflated performance of tyres

[illegible]	[illegible]	[illegible]
[illegible]	1–1½ miles	Up to 100 miles
[illegible]	5 m.p.h.	Up to 50 m.p.h.
[illegible]	Very difficult Tyre destroyed	Driving safe and easy Tyre normally re-usable

SLIDE 6

With this technique it has been possible to improve considerably the punctured running performance, with the additional advantage of greatly increased safety. The distance a car can travel – after a puncture – goes up from (slide 6) about 1½ miles (2km) to at least 100 miles (160km). The speed of travel goes up from 5 mph (8 kph) to 50 mph (80 kph) and driving is no longer difficult but is, by contrast, quite safe and easy, and instead of destroying a tire it is now normally reusable (slide 7).



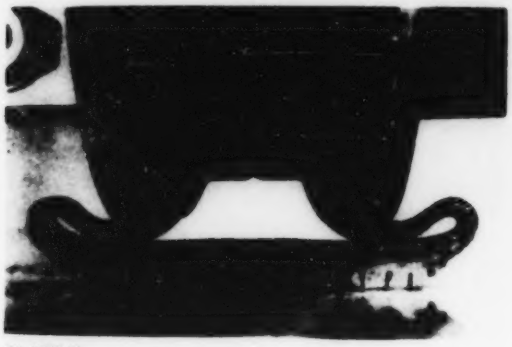
RUN FLAT:
PRINCIPLES OF DESIGN

Design tyre flat from the ground upwards
Consider normal inflated condition later

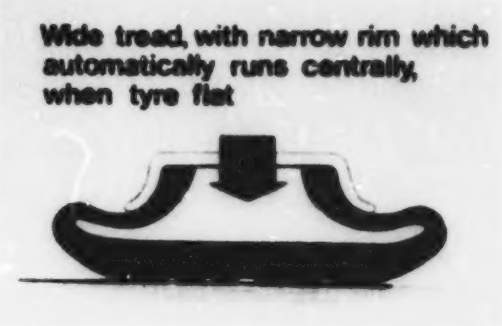
SLIDE 7

Let's look at the concept in more detail.

First of all we designed the tire flat, without any air, from the ground upwards (slide 8). And here's a photograph of a cut-away tire which was taken in our laboratories (slide 9).



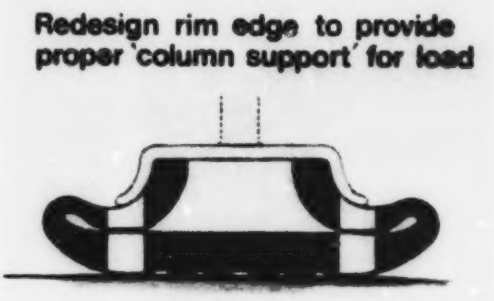
SLIDE 8



Wide tread, with narrow rim which automatically runs centrally, when tyre flat

SLIDE 9

The tire, of radial construction, has a wide tread with a narrow rim. This ensures that when the tire is deflated the load is transmitted directly on to the tread area and runs centrally under most normal driving conditions (slide 10).

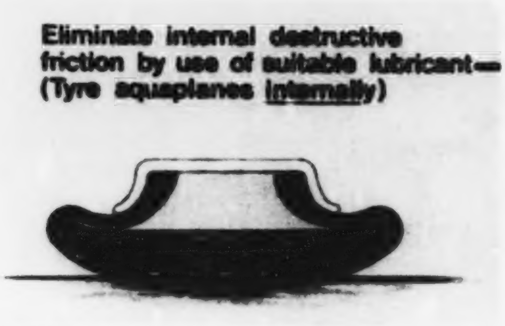


Redesign rim edge to provide proper 'column support' for load

SLIDE 10

By firmly locking the beads in position when the tire is both inflated and deflated, the coherent structure of the tire is maintained. This technique ensures full "column support" for the load.

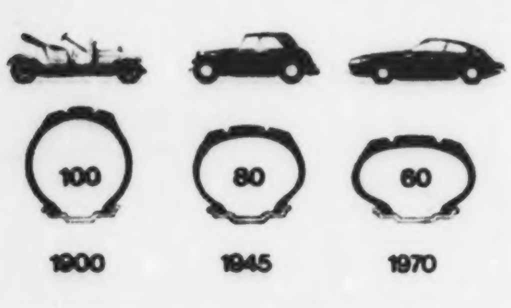
Internal friction, which of course is highly destructive (slide 11), is eliminated by the use of a special



Eliminate internal destructive friction by use of suitable lubricant— (Tyre aquaplanes internally)

SLIDE 11

lubricant which, though normally captive, is released when the tire is flat. This lubricant also fulfills several other functions. Firstly, it provides a temporary seal against a very high percentage of normal punctures. Secondly, it generates a small vapor pressure which causes a slight reinflation and assists mobility and endurance. And thirdly, it fulfills another function in that it acts as a heat transfer agent from "hot spots" to cooler areas of the tire (slide 12).



SLIDE 12

The logical application of these principles leads to the use of a low profile radial tire, and ideally a 60% ratio tire. The trend towards such low profile tires is already very much in evidence both in Europe and the U.S.A. Here you can see the principal stages in the progression of the tire profile. You will therefore see that our new development is in the mainstream of tire technology.

So much for the tire itself. But let us not forget rim and wheel considerations. There are two basic development areas. Firstly, there is a design which is virtually a rim or wheel without a well, and most of our initial development work has been done with this design. Secondly, we are developing a demountable wheel which allows the tire to be removed from it. That is the background to our development which we see as a major advance in the tire and wheel concept (slide 13).

SLIDE 13

—offering for the first time the mobility of a vehicle designed without a spare wheel.

ANTI-LOCKING BRAKE DEVELOPMENT IN THE UNITED KINGDOM

MR. P. OPPENHEIMER, *Technical Legislation Manager*

Girling Limited

I am privileged to present some highlights from our development work on anti-locking brakes, as part of the British contribution to the ESV program. Several relevant papers by Automotive Products, Jaguar Cars and Lucas/Girling are included with the official U.K. literature for the ESV delegates and the Press corps.[1]

History

The development of anti-locking braking systems originated in Britain more than 20 years ago. One of the earliest examples was the Dunlop Maxaret device, and in 1956 a Jaguar Mk VII Saloon was equipped with this system controlling the individual wheels. It quickly became apparent that the expected advantages were achievable.

A film may be shown to illustrate these early achievements.

Unfortunately, the relatively simple Maxaret unit required an elaborate flow-type hydraulic braking circuit and thus became too expensive to be marketed. At a later stage, the Ferguson 4-wheel-drive system was developed, which enabled a single Maxaret unit to be used to control the vacuum brake booster. This reduced the cost of the system to more modest proportions and enabled the Jensen FF Saloon to be introduced in 1966 – the world's first production car with anti-locking brakes.

Current Status/Hardware Availability

Despite these early successes, few commercial applications of anti-locking systems have been realized. In fact, it was only the recent legislative activity in Sweden and the U.S. – culminating in the ESV program – which has once again focused the attention on the development of anti-locking brakes. Accordingly, several such systems have been developed in the U.K. and are currently being evaluated by the manufacturers and the legislators. Two typical examples of the latest electronic 4-wheel anti-locking system by Automotive Products and Lucas/Girling are exhibited here at TRANSPO on the British SSV 1 and SSV 2, respectively.

Developments in Progress

The ESV braking specification offers little incentive to the development of anti-locking brakes. This has already been mentioned by R. Cochrane at the 2nd ESV Conference in Stuttgart.[2]

In order to achieve a real improvement in road safety, the U.K. brake manufacturers – and the vehicle manufacturers – expect anti-locking brakes to cope with a variety of other conditions, beyond the straight-line stopping requirements in the ESV specification.

For this reason, our development work is continuing and we are investigating the performance of anti-locking systems over a wide range of intrinsically hazardous conditions in terms of road surfaces and handling maneuvers.

I will briefly summarize the status of some of these investigations.

The significance of locked wheels

Under normal, uniform surface conditions, the consequences of wheel-lock are well-known:

> If the front wheels lock, or if all 4 wheels lock, then the car travels in a straight line. If only the rear wheels lock, then the car tends to spin round. If all 4 wheels do *not* lock at the same instant, then the behavior of the car is dependent on the time interval between the locking of the front wheels and the rear wheels; if the rear wheels lock ½ second before the front wheels, this may be sufficient to spin the car round.

But in practice, other road surface conditions can occur and lead to accident situations. For example, icy patches or pools of water are often encountered and this can be simulated by testing the car while straddling 2 different surfaces.

Under these conditions, when the front wheels lock, the front end of the car moves across to the higher friction surface and providing the rear wheels are still rotating, it will follow the new directional line and remain reasonably stable — because the yaw angle of the car will not normally become excessive. But if the rear wheels become locked across a differential-friction surface, irrespective of whether the front wheels are locked or not, the car will develop an exceptional degree of yaw, and dependent on the speed of approach, it may spin round many times.

A film may be shown to illustrate these aspects.

Rear-wheel control

Rear-wheel anti-locking systems can provide stability under all conditions and good stopping distances — even better than 4-wheel systems on rising-friction surfaces such as loose gravel and fresh snow. Furthermore, if the car is out of control (through excessive maneuvering), applying the brakes *hard* can help to restore stability, and thus ensure frontal impact with minimum risk to the occupants. Any failure in the anti-locking system can provide an adequate residual performance to meet the ESV specification.

Consequently, there is a strong technical argument for the immediate introduction of rear-wheel anti-locking systems, which would make a significant contribution to road safety by eliminating accidents due to rear-wheel lock-up. Such systems are now available to meet the ESV braking specification. The resultant service experience in terms of reliability and maintenance requirements would be invaluable towards the eventual introduction of 4-wheel anti-locking systems.

4-Wheel control

4-wheel anti-locking systems can provide controllability, as well as lateral stability. This enables the driver to brake *and* steer in an emergency, without recourse to the skills which are currently necessary to execute such maneuvers safely.

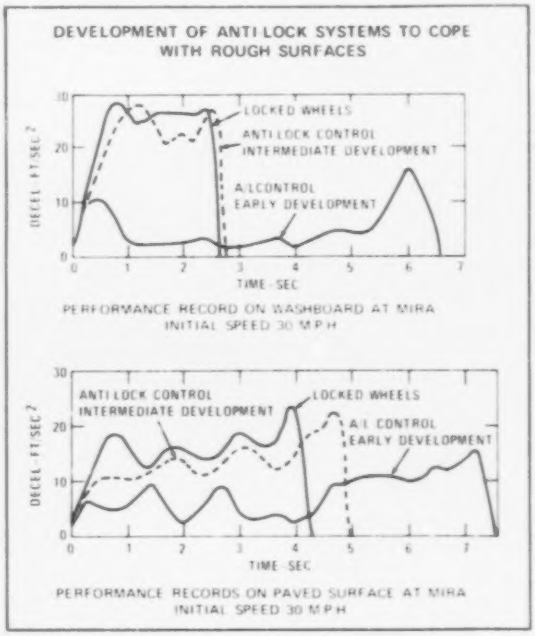
In theory, the 4-wheel system enables all the available tire-to-road friction to be utilized and thus provide the maximum braking potential. But in practice, there are many fundamental problems and technical difficulties, some of which have so far defied solution.

For example, steering control enables the driver to over-demand in relation to the available adhesion and thus controllability can lead to instability; in other words, the potentially safer 4-wheel system can become less safe than the rear-wheel system.

On rising-friction surfaces — mentioned previously — locked wheels will always achieve the shortest stopping distances — albeit without stability or controllability. While 4-wheel systems can provide both stability and steering control, further work is needed to approach the optimum compromise between steering and stopping.

Another interesting aspect of our development program concerns the behavior on rough surfaces (Fig. 1). Wheel bounce can cause significant variations in wheel rotational speeds and thus produce unwanted signals which 'confuse' the electronic interpretation of the modulation required to prevent wheel locking. As a result, the stopping distance can be worse than if no anti-locking system is fitted and much work is in progress to eradicate this deficiency.

Manual transmissions, which are still used on the large majority of European cars, pose some additional problems. For example, on rear-drive cars, releasing the accelerator pedal at 40 mph in 2nd gear on a low adhesion surface may cause the car to spin round


DEVELOPMENT OF ANTI-LOCK SYSTEMS TO COPE WITH ROUGH SURFACES

PERFORMANCE RECORD ON WASHBOARD AT MIRA
INITIAL SPEED 30 M.P.H

PERFORMANCE RECORDS ON PAVED SURFACE AT MIRA
INITIAL SPEED 30 M.P.H

FIGURE 1

before the driver can transfer his foot onto the brake pedal: a difficult problem for the brake engineer.

Extreme cold temperatures can cause sluggish operation of anti-locking systems and further work is needed to determine acceptable performance levels at sub-zero temperatures.

And evidence has been produced, which suggests that radio-frequency interference cannot be discounted as an aspect which needs further investigation.

Failure modes of 4-wheel systems are extremely critical, because they could make the car more dangerous than a car without anti-locking brakes — and a comprehensive failure monitoring/indication circuit becomes essential.

Various 4-wheel system control combinations are possible and Fig. 2 illustrates relevant stopping distances on a 2:1 variation of friction surfaces. Individual front-wheel control reduces stopping distances on a 2:1 variation of friction surfaces. Individual front-wheel control reduces stopping distances by about 20%, but individual rear-wheel control adds less than half this improvement. Consequently, individual front-wheel control with rear-axle control is usually the best economic compromise. The resultant pull on the steering wheel is sometimes noticeable, but not embarrassing.

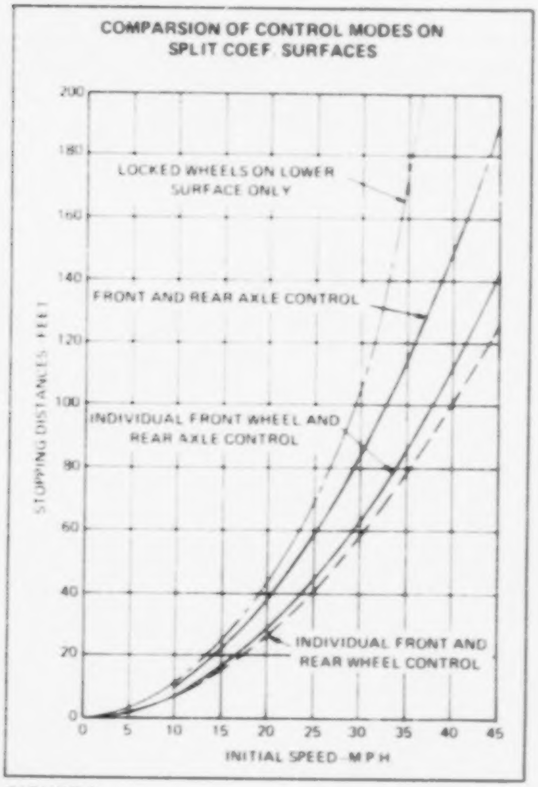


FIGURE 2

Legislation and Performance Standards

The legislative philosophy also has considerable bearing on the design and development of anti-locking brake systems. If any system deterioration is to be anticipated, then a residual level of service brake performance must be provided in the event of any single failure. Any such failure should be indicated to the driver; and the effectiveness of the anti-locking system should not be dependent on any component whose satisfactory function is not known or which is normally at rest.

The proposed ESV specification performance quotes 80% adhesion utilization on surfaces from 0.2 to 0.8 adhesion. In practice, it is very difficult to verify these conditions; for example, the adhesion characteristics are significantly affected by the tires and the speed of the vehicle. We have found that the most reliable and reproducible parameter for the assessment of anti-locking brake systems is the "locked-wheel" stop. This datum measurement eliminates the troublesome tire/road interface from the variables, and in road safety terms, it reproduces the actual panic braking conditions in an accident situation.

With the same tires and on the same surface, all cars achieve very similar locked-wheel stopping distances. We would suggest that the addition of an anti-locking system should not significantly increase the stopping distance beyond the locked-wheel stop and the overall performance should be within the ESV specification. A failure in the anti-locking system should provide the 45% residual braking efficiency — without skidding.

Additionally, there should be handling tests to evaluate the anti-locking system performance during panic braking on a curved track, on differential-friction surfaces and during chicane or 'overtaking' maneuvers.

The U.K. Government has already submitted such initial proposals to the Economic Council for Europe (ECE) this year.[3]

In conclusion, the British Motor Industry has accepted the challenge of brake system development under the ESV program and welcomes this opportunity of demonstrating some of our achievements towards accident avoidance and general road safety.

REFERENCES

1. Relevant technical presentations from the TRRL Symposium "Towards Safer Road Vehicles" by: Ingram, B. (Girling Limited); Knight, R.J. (Jaguar Cars Limited); Parker, S.M. (Automotive Products Group).

2. ESV braking specification, and Cochrane, R. (Girling Limited) – "Performance specification for anti-locking systems"

3. UK draft proposal for anti-locking brakes (ME/Trans/72/D.15)

AN ERGONOMIC APPROACH TO INSTRUMENTATION

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Smiths Industries Limited

With road safety in mind the emphasis is on how to make the driver's task easier, particularly under dense and critical traffic conditions, so that he may devote his attention wholly to the road. This is a general problem, but the driver of the commercial vehicle particularly at the heavy end of the range, has undoubtedly the most demanding job. These vehicles require comprehensive instrumentation for monitoring the performance of a complex system. It is therefore essential to produce the necessary information in a form most easily assimilated. To start with, those instruments which require frequent attention, must be grouped together and positioned as close to the driver's normal line of vision as road visibility considerations will permit. Next, the layout of the information display must provide instant recognition of whether or not the service gauged by the instrument is in a satisfactory condition or at risk. The disposition of the various instruments relative to each other is also important and should follow an accepted standard to avoid confusion when drivers change vehicles.

Because it is important to group only the most-essential-for-driving instruments in front of the driver, some form of "collective warning" must also be incorporated with the "driving instrumentation." This warning device or attention getter ideally takes the form of a large brilliant red warning light, sometimes coupled with an audible signal. If any of the services monitored by the attention getter are at risk the message is loud and clear:

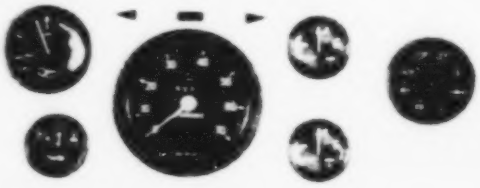
"STOP! and then investigate in more detail the actual cause."

A layout of the "Driving Instruments" for a commercial vehicle has been conceived based on these considerations. The important instruments are the Speedometer, which forms the center piece, Brake Gauges to the right, and Engine Gauges, Tachometer and Oil Pressure to the left. A warning light cluster with large red attention getter is placed high up to one side linked to sensors for:

- Brake Pressure Low
- Brake Fluid Low
- Anti-Locking Brake Failure
- Oil Pressure Loss
- Coolant Loss
- Tire Pressure Low
- Power Take-off
- Differential Lock
- Stop Light/Lamp Failure

The first five of these services should also be linked with an audible signal. Depending on the special nature of a vehicle other services might need to be linked to the "attention getter." In the case of Passenger Service Vehicles warning must also be given when the door is jammed open, or when the emergency door is not properly closed.

The two green direction lights, the blue high beam and red no charge indicator lights complete the driving instrumentation.



A number of other instruments are necessary or at least highly desirable to provide the driver with a check on services such as fuel contents, battery state of charge, coolant temperature, oil temperatures etc.

They should be located conveniently for the driver to see when it is safe for him to do so. In addition to these instruments there is a category of lights which monitor services that are not subject to emergency action but which require attention when convenient. To quote but a few: Low Fuel, Exhaust Temperature, Air or Oil Filter Pressure, Brake Lining Wear, etc.

These supporting instruments and warning lights can be collectively described as secondary instrumentation.

The choice of driving instruments is determined by legal requirements and/or because they are necessary for safety and economy.

Except in the case of the speedometer, the information display for the various instruments is determined by the type of service gauged and to impart a message at a glance. Moreover, all pointers aligned roughly in the 12 o'clock direction is significant of all being well (again speedometer excepted).

The brake gauges are cirscale instruments because in practice fairly large changes in pressure can take place on braking repeatedly and a correspondingly large pointer movement will highlight this effect and will contribute to pre-warning the driver when the pressure drop approaches the level where the emergency warning finally takes over. The brake gauge dials are color zoned. Green for normal and **RED** for **STOP**. They project a message and do not require interpreting faculties on the part of the driver.

The oil gauge on the other hand has a shorter scale. Large changes in oil pressure do not normally take place except under engine idling conditions. Therefore, when motoring, there is no abrupt cause for pressure changes, and if the pointer strays from the normal green safe zone, a fault is developing. This prior warning will give a little more time to the driver than the abrupt emergency audio/visual signal preceding complete pressure loss. The scale shape differentiates between the oil gauge and the brake gauges. The color code: green for safe and [illegible] for emergency applies to both. A nominal [illegible] mm diameter is recommended for both types of gauge.

The third category of driving instrument, the revolution indicator, is required for diesel engine applications. The dial zones for a specific engine can be selected to give **NORMAL** indication for the optimum speed range and danger zones at other speeds to prevent over-revving and uneconomical driving. The revolution indicator is an 80 mm diameter cirscale instrument. A large pointer movement is desirable to assist the driver to maintain a fairly constant engine speed.

The speedometer is the last of the driving instruments and it is the most important! Whereas, at a pinch, the brake and oil gauges and the revolution indicator could be omitted, while still retaining the emergency warnings, as is the case on most private cars, the speedometer remains essential. Its purpose is more than to assist the driver in observing speed limits. It is truly a navigating instrument without which adjustment of the vehicle speed to a safe value at all times would be extremely difficult and often impossible.

The following are some of the variables which individually and in combination influence the choice of safe speed:

- Vehicle size
- Load
- Weather conditions
- Visibility
- Type of road surface
- Traffic density
- Degree of wear on tires
- Daylight, half light or night

With the speedometer plus the driver's skill and experience an optimum speed can be selected to meet most conditions. This may, of course, necessitate frequent consultations of the speedometer by the driver, and every time this happens he takes his eyes off the road.

There are situations and weather conditions when the driver cannot afford to look away from the road and then he uses his judgment to assess his speed, but not always successfully.

We are all aware that poor visibility, fog for instance, and night driving distort judgment of speed. Also after spells of motorway driving when entering ordinary road networks 40 mph or 30 mph seem a mere crawl. Relying only on driver instinct, the speed judgment under such circumstances can literally be miles out. The Road Research Laboratory Specialists have investigated these phenomena in depth and their findings have been well publicized.

The solution seems to lie with some means for communicating speed to the driver while he retains his vision of the road ahead.

PERIPHERAL VISION AS A DRIVER AID

Drivers of commercial and private vehicles would benefit from the ability to monitor speed while keeping their eyes on the road.

The private car driver is probably slightly better off, in this respect, than his commercial equivalent, if his car has a boldly styled speedometer mounted close to the lower edge of his windscreen. This is because he can almost retain the pointer in the corner of his eye, once he has captured it, whereas the commercial vehicle man must dip his vision line much lower to see his speedometer.

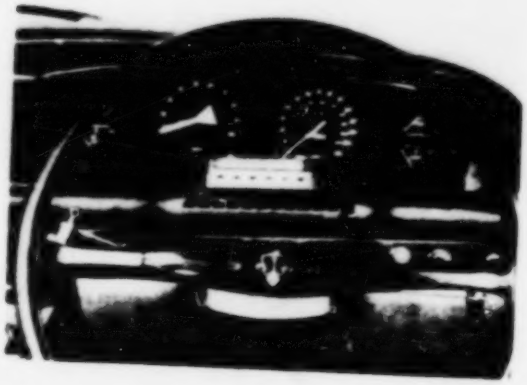
We experience this effect constantly in everyday life, without it we would forever walk into furniture or lamp posts etc. It is defined as peripheral vision. In effect it is seeing from the corner of one's eye, and the perception of objects becomes stronger as they approach more closely the direct line or cone of vision.

We can take advantage of the phenomenon by designing expressly to derive maximum benefit from it.

The ideal circumstance is a matt black background against which a bold white beam rotates. This display should be hooded and should virtually abut the lower edge of the windscreen. It should not be cluttered either side by other distracting features. Another requirement is large movements for small speed changes. We have established that a bold white pointer with a squat triangular tail provides very good peripheral perception of displacement. With 10 mph change in speed per 90° angular deflection one can readily observe speed without taking one's eyes off the road. However, one must be able to distinguish between 20 mph and 60 mph or 30 mph and 70 mph. One complete rotation of the bold white pointer signifies a 40 mph speed change.

A peripheral vision speedometer is effective only if mounted fairly close to the line of vision, and thus imposes severe styling limitations. For this reason it is not readily adaptable for commercial vehicle application.

The peripheral vision range is by no means constant. Some people are more generously endowed with this capacity than others. Deliberate concentration on something close to the limit of one's peripheral vision can be a strain and tiring to the extent that the object may temporarily disappear completely. Another possibility is that some drivers might incline to use the instrument like an ordinary speedometer.



HEAD-UP DISPLAY

I have stated that under certain conditions the only safe way to ensure that the driver has correct knowledge of his vehicle's speed is to bring it to his attention without causing him to look away from the road. This is because shifting his eyes from the road to the speedometer, focusing on this instrument and then looking back to the road and refocusing takes an average 1.5 seconds time, and appreciably longer for the older driver. At 60 mph this corresponds to 44 yards or more of travel with eyes averted from the road and a lot can happen in this distance.

We also know that judgment of speed under given conditions can be suspect, and that disastrous consequences may result from decisions based on incorrect assumptions.

Peripheral perception of a well-placed instrument is practical only in limited applications, and even then

is dependent on the individual, whether he can or whether he will accept the information presented to him in this way.

What then if we place an image of the speed right into the roadway where the driver normally looks so that it is just as easy for him to see as the lamp post or pedestrian crossing ahead, and no more distracting that such objects?

The TRRL had investigated this problem and we were convinced by their demonstrations and logic that such an approach, if feasible for general vehicle application, would present a break-through for safer driving.

We were pleased and excited when the TRRL invited us in mid-1970 to undertake a development contract for a present day production design of speed head-up display. The object was and is to project a speed image into the windscreen very close to the driver's line of vision, and to focus this image sufficiently far ahead for the driver to see while looking at the road.

In agreement with the TRRL we chose a Rover 2000 car for the exercise. The Rover by the shape and rake of its windscreen was by no means the easiest vehicle to deal with, and it was thought that if a satisfactory solution could be found for this car, then that solution could be adapted to other cars fairly easily.

Our solution is simple to achieve with present day techniques and lends itself presently to adaptation of solid state devices. A speed image is provided by passing a skeleton printed disc in front of a light source. This image is then reflected by a suitably shaped mirror into the windscreen. At least two speed figures e.g. 40 and 50 appear together and move relative to a datum. The sense of the movement indicates rising or falling speed.

Complete collimation has been found impractical because the windscreen is part of the optical system. Any variation in the windscreen curvature has a pronounced effect on a distant focused image, leading to image separation. However, a compromise near distance focused image is more tolerant of windscreen variations, and can still be assimilated by the driver without refocusing his eyes.

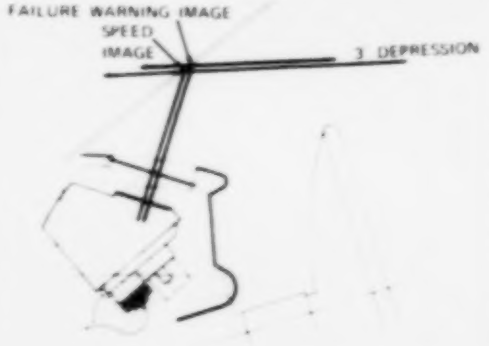
Laminated windscreens lead to a multiplicity of overlapping images. The phenomena can be overcome by a local highly reflective area in the windscreen. Economical means for achieving such a coating are currently under investigation between TRRL, Smiths Industries and windscreen manufacturers.

In the course of our development work we have consulted specialists in optical systems and in ophthalmology, and we believe that our solution is acceptable to the human eye and does not lead to strain or other undesirable side effects.

The image intensity will be modulated automatically against ambient light conditions with an overriding intensity control to suit individual tastes. Image color, through consultation and experiments, has been chosen as orange, with the possible refinement of an additional filter for night driving.

The installation of the equipment requires somewhat more space than the conventional speedometer, but it is anticipated that for new vehicle application suitable provision can be made in the design of the facia structure for its accommodation. The equipment will also incorporate vertical image adjustment to suit the eye positions of different drivers.

A DIAGRAMMATIC REPRESENTATION OF THE HEAD-UP DISPLAY SPEEDOMETER INSTALLATION



To make the head-up display truly comprehensive an emergency warning signal and a safe following distance indicator should ideally be incorporated in the image projected into the windscreen. The warning signal is relatively simple to achieve and to project. It will take the form of an intense warning light linked only to these vehicle services whose failure or impending failure constitute a safety hazard.

The safe following distance or station keeping indicator (S.K.I.) is under investigation at the TRRL. Extensive development work may be required to produce a satisfactory production solution. In principle, an image whose width varies with vehicle speed, is projected into the windscreen.

The correct minimum following distance has been chosen when the width of the car ahead appears similar in size to the projected image. The safe following distance is based on reaction time plus time for braking to become effective and should, we are advised, be of the order of one second.

It is not in fact, the distance required to bring the following car to a standstill clear of the leading car subsequent to the latter striking an immovable object. Following distance based on this type of consideration would be impractical.

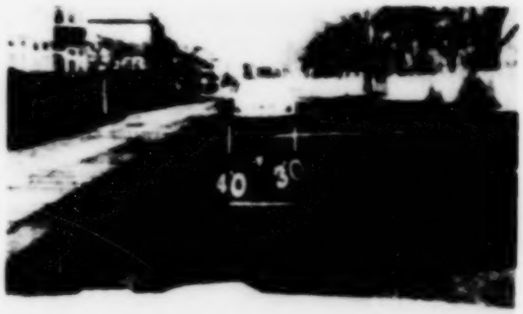
1. It would severely limit the traffic carrying capacity of road systems.
2. It would be difficult to enforce and the large gaps at high speed might quickly be reduced by hedge hopping traffic.
3. The braking distance is dependent on a number of variables such as weather condition and road surface which are quite independent of the car. If we add to these the effect of tire wear and an acceptable spread of brake efficiency then we realize that no braking distance to meet all conditions could be specified.

However, a safe following distance based on reaction time plus the time for braking to become effective will ensure that following traffic is capable of adapting itself to speed variation of the leading traffic independent of road and weather conditions. Also small variations in vehicle width become less important. In the U.K., for instance the width of private cars varies no more than ±10% about a mean, and commercial vehicles are marked at the back by a yellow and red striped band equivalent in length to the mean car width.

The station keeping image is likely to be in the form of two parallel vertical lines focused well ahead of the vehicle and spaced proportional to vehicle speed. It is important that this image remains true irrespective of head movement.

European cars have a variety of curved windscreens, and we know from extensive investigation, that the curvature variations for a given shape of windscreen are likely to lead to unacceptable distortions of a variable size, distant focused image of this type, distortions which are hardly noticeable and not distracting in a simple speed head-up display. It follows therefore that development work on the S.K.I. will include investigations and development of new windscreen manufacturing techniques to produce a local controlled area into which the image is projected.

Two Rover cars have been equipped with STAGE I prototype speed head-up displays. One of the cars has been with TRRL for some months for practical assessment. The other car is a development vehicle, which has also been used occasionally for demonstrations within the industry. The TRRL/S.I. joint intention is to equip in addition a limited number of the major car manufacturers' vehicles with prototype installations so that a more intensive assessment and evaluation of the speed head-up display can take place.



In the meantime, we are continuing with our objective to produce a production design and costs and final prototypes towards the end of this year.

VEHICLE DIAGNOSTIC EQUIPMENT

A growing number of sensors is being installed in private and commercial vehicles. The sensors related to the performance of expensive equipment on which the drivers' and other roadusers' safety depends will certainly be more numerous and more sophisticated for commercial vehicle applications. A list of the services already monitored helps to get the situation into perspective.

Brakes
Brake fluid level
Reservoir low pressure
Anti-lock system failure
Brake lining worn
Parking brake

Coolants
Coolant level
Coolant temperature
Coolant loss

Oils
Engine oil pressure
Engine oil temperature
Engine oil level

Speed
Engine overspeed
Turbo charger overspeed

Other functions
Tire pressure
Air filter pressure drop
Exhaust temperature
Generator
Rear window demist

Lamps
Side/Stop light failure

Differential oil
  temperature
Transmission oil
  temperature
Torque converter
  temperature
Oil filter pressure drop
Headlights
Dipped lights
Fog light
Rear fog light
Reversing light

These sensors are now being used in warning systems, but they have a greater contribution to make. Analysis of the frequency and duration of adverse conditions will help in planning proper maintenance of the equipment and will also provide the means for ensuring that attention is paid to warnings when they occur.

Schemes are already afoot for diagnosing conditions with the vehicle stationary. This readily applies to all level measurements and electrical continuity and other electrical parameters that can be evaluated with a suitable input. Such schemes do not, however, provide a feedback on conditions in service. To do this a built-in recording system is required. We suggest a chart recorder with line recordings on parallel tracks when a safe parameter is exceeded. The recorder would be driven at constant speed only when the engine is running, and would therefore serve also to log engine hours.

The chart would supplement the information obtained from engine stationary diagnostic equipment to give an overall picture of vehicle conditions based on which the amount of servicing necessary can be determined.

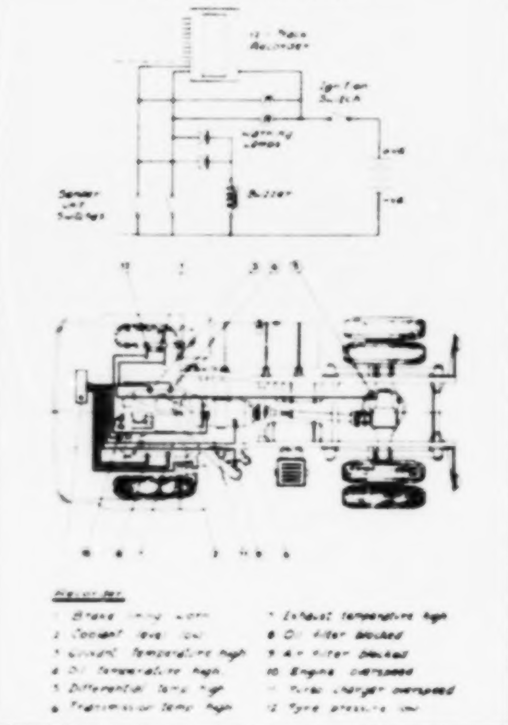
A schematic for a comprehensive on-board in service monitoring system and a static plug-in system have been produced.

An on-board recorder with 12 tracks is proposed with a solid state indicator lamp which remains on if any one of the services linked to the recorder has been at risk. Opening the recorder to scan the chart cancels the indicator light.

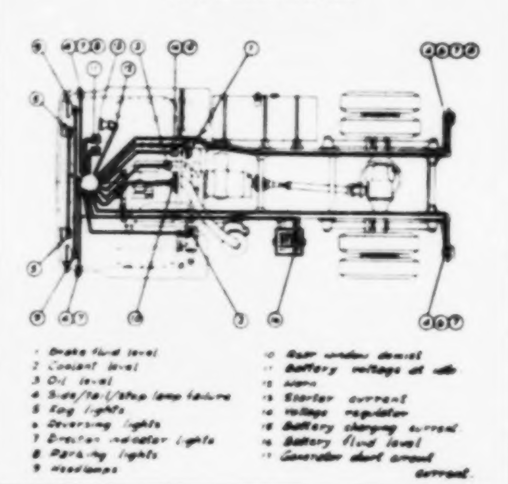
In the schematic we have linked to the recorder sensors for:

Brake lining worn
Coolant level low
Coolant temperature
  high
Differential tempera-
  ature high
Transmission tem-
  perature high
Exhaust temperature high
Oil filter blocked
Air filter blocked
Engine overspeed
Turbo charger over-
  speed
Tire pressure low

IN SERVICE MONITORING SYSTEM


12-Track Recorder
Ignition Switch
Warning Lamps
Buzzer
Sender Unit Switches
+ve
-ve
Recorder
1 Brake lining worn
2 Coolant level low
3 Coolant temperature high
4 Oil temperature high
5 Differential temp. high
6 Transmission temp. high
7 Exhaust temperature high
8 Oil filter blocked
9 Air filter blocked
10 Engine overspeed
11 Turbo charger overspeed
12 Tyre pressure low

STATIC MONITORING SYSTEM


1 Brake fluid level
2 Coolant level
3 Oil level
4 Side/tail/stop lamp failure
5 Fog lights
6 Reversing lights
7 Direction indicator lights
8 Parking lights
9 Headlamps
10 Rear window demist
11 Battery voltage at idle
12 Horn
13 Starter current
14 Voltage regulator
15 Battery charging current
16 Battery fluid level
17 Generator short circuit current

Those services which are coupled to a visible and audible warning on failure require immediate attention and would therefore not be linked with the recorder e.g.

Low brake reservoir pressure
Coolant loss

Oil pressure loss
Anti-lock brake failure
Brake fluid low

The following services and components (from those listed) would be connected to the static plug-in diagnostic system:

Brake fluid level
Coolant level
Oil level
Lamp failure/Stop & side lights
Fog lights
Reversing lights
Turn indicator lights
Parking lights
Headlights
Rear window demist
Battery voltage at idle
Horn
Starter current
Voltage regulator
Battery charging current
Battery fluid level
Generator short circuit current

The static diagnostic system has the further advantage of providing a ready means for the initial on-vehicle inspection of the devices linked to it.

There is scope for increasing the number of sensors so that the diagnostic system can be extended to include all routine servicing functions. When this has been done we shall have achieved the ideal situation. Servicing (and this excludes major overhauls) will be done by exception, and as a result of a weekly computer check on the hard worked commercial vehicle. For cars, normally a monthly check may be sufficient.

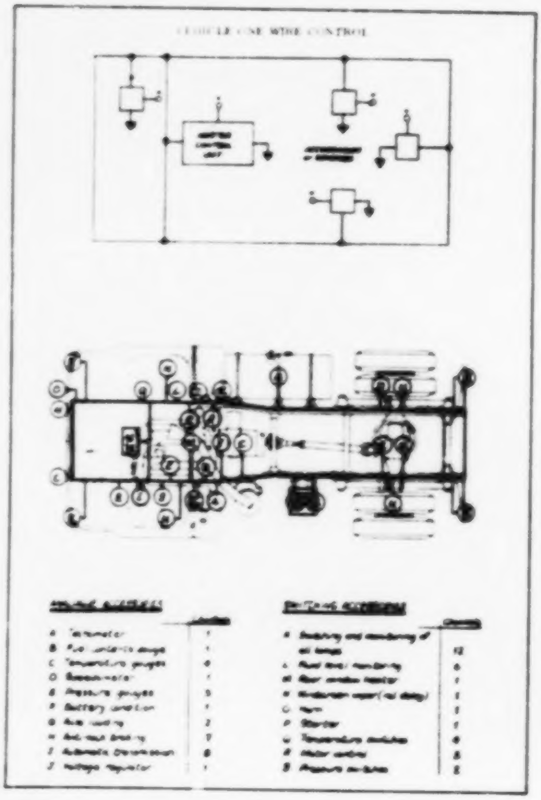
A further refinement would be to include the means to monitor M.O.T. requirements compliance with which is currently subject to annual certification. This could be extended to monitoring emission control and other controls enforceable by legislation.

FUTURE INSTRUMENTATION

Now that Large Scale Integrated Circuits (L.S.I's) are becoming available at low prices, it is possible to consider electronic circuits of great complexity as solutions to old problems. These circuits, though complicated, represent in terms of reliability, stability and robustness a simplification and improvement over current practice.

Smiths Industries' Electronic Engineers have anticipated the advances in Integrated Circuit manufacture and have designed a "One Wire" Electronic Control system for Switching and Telemetering Automobile Electrics.

All wiring on a conventional vehicle is replaced by a ring main system consisting of a power lead and a control wire passing around the perimeter of the vehicle. All electrical accessories are connected to this ring at the nearest point via an electronic module. A control unit situated at the dashboard is also connected to the same ring.



A switch, operated on the dashboard control, alters a particular code in a main sequence, transmitted down the control wire every millisecond. The appropriate accessory electronic module detects that code and stores the information. When the correct code is received four sequential times, nominally after four milliseconds, then the accessory is operated. If the accessory fails to operate, a FAIL signal is returned to the control module and a warning indicator is illuminated.

A particular feature of the S.I. system is the ability to accept analog or changing level signals. As an example, a tachometer sensor connected to the ring at the engine has a code location. This is detected, again at the control unit, decoded and displayed in the conventional way on an instrument. Further locations can be made available for other instrumentation i.e. Temperature, Fuel and Pressure gauges. Other examples are shown in Fig. 8. The battery may also be connected at any point. A break in the ring does not stop the operation, on the same principle as domestic ring mains.

The size of the integrated circuit modules is estimated to be about 1 inch cube. They would be completely encapsulated and coded by their channel numbers.

Once such a system is installed on a vehicle several advantages can be demonstrated.

(a) Less copper wiring. Also the main power lead could be made of aluminum.
(b) Sensors and accessories become easier to fit. Panel switches pass only signal current.
(c) Unit automatically indicates non-operation i.e. is self-checking.
(d) Connection of test signals to control wire during service can interrogate all accessories.
(e) Modifications and additions to vehicle electrics can be made more easily.
(f) Signals from various sensors can control other parameters i.e. Anti-lock Braking, Speed Control, Automatic Transmission.
(g) The loom fixture costs would be greatly reduced.
(h) Eases connection and disconnection of trailer electrics.

It is envisaged that within five to ten years such a system could be fitted to a vehicle and economically replace all present wiring looms, plugs and sockets etc., and produce a more reliable and more versatile connection system.

A vehicle equipped with one-wire control contains a system through which all the services linked to it can be interrogated for diagnostic purposes. An off the vehicle computer could be linked to the system probably at a connecting point on the vehicle control unit.

Additional sensors for monitoring functions not normally controlled or gauged on-board vehicle can readily be connected to the one wire system in the same way as an optional accessory. What is necessary at the outset is to ensure an adequate number of coded functions is allowed for and that the sweep frequency will accommodate them.

Another advantage of the Electronic one-wire control system is the ability to monitor "in service" conditions, and to store any deviations from set limits without a more conventional on-board recorder. When connected to the static diagnostic equipment this stored information would also be released. Naturally the on-board vehicle control unit would become more complex to the extent of housing also a memory system.

With an advanced vehicle electric system of this nature it is highly probable that the information display will also undergo radical changes. Although we have already established that the one-wire system will operate conventional readouts, these too are likely to benefit from technological advances.

The ideal information display concept developed earlier in this article can now be wholly achieved. In addition to the speed head-up display and a head-up warning when a critical service is at risk, only one strategically placed display screen is required for all other services. The advantage is that the driver of the vehicle can be aware of his speed without taking his eyes off the road and traffic. At the same time he can rely on having imposed, near his line of vision, warning of critical services at risk. Therefore nothing vital need distract his attention from the road. When he does want to check dashboard instrumentation, there is only one place to look for.

The display screen would be linked to the control unit of the one-wire system, and by exception would display any service that happens to be at risk. For instance, if the oil pressure had dropped too low the **STOP** warning would be flashed into the windscreen (possibly coupled with an audible warning) and the display screen would identify the service at risk and in this case the actual oil pressure. When a less critical service demands attention, one of two large warning lights, flanking the screen would light up, and the screen would identify the service and indicate the magnitude of the parameter interrogated. The two warning lights are one **RED**, the other **YELLOW**, red being the more urgent.

Figure 10 shows "Low Fuel" on the display screen coupled to the large yellow warning light.

If several services compete for the screen simultaneously they would appear sequentially with a dwell of say 3 seconds.

The Head-up **STOP** light and the **Red** or **Yellow** warning lights would stay on continuously.

Another function of the display screen would be that under normal circumstances, i.e. when no service is at risk, the driver could monitor any one of the connected services by push button demand. The display screen would automatically be cleared after 3 seconds.

Conceivably the display would utilize any one of the solid state systems currently under development. However, a display as flexible as the picture on a television screen would obviously be most attractive if commercially and technically viable. Certainly even today it is technically possible to achieve very compact solid state displays with liquid crystals, light emitting diodes and plasma panels.

SSV2 ELECTRICAL EQUIPMENT

MR. CHRISTOPHER S. RAYNER, *Chief Engineer*

Electronic Design Group, Joseph Lucas Limited

LIGHTING EQUIPMENT

Lighting is required on a vehicle in the first instance for the driver to see by. It is also necessary to provide tail lamps so that the attention of other drivers may be drawn to the existence of the vehicle. To indicate driver maneuvers brake and turn signal lamps are also fitted. Inevitably the use of these lamps has an interaction with other road users and must be as inoffensive as is practicable.

The Lucas-Martin Load Levelling System

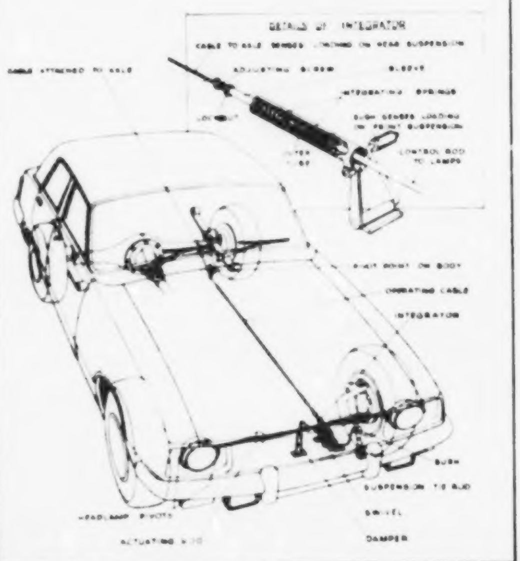

DETAILS OF INTEGRATOR
CABLE TO AXLE SENSES LOADING ON REAR SUSPENSION
CABLE ATTACHED TO AXLE
ADJUSTING SCREW
SLEEVE
INTEGRATING SPRINGS
LOCKNUT
BUSH SENSES LOADING ON FRONT SUSPENSION
OUTER TUBE
CONTROL ROD TO LAMPS
PIVOT POINT ON BODY
OPERATING CABLE
INTEGRATOR
BUSH
SUSPENSION TO ROD
HEADLAMP PIVOTS
SWIVEL
ACTUATING ROD
DAMPER

FIGURE 1

Modern headlamps are produced to tighter tolerances than was previously possible and to take full advantage of this accuracy of direction of the beams is of the greatest importance. It is expected that the European requirements shall fall within the range of ±½° from the nominal. The accuracy of the system installed on the vehicle is consistently ±¼° over a wide range of loads in any given application. The system operates by transmitting movements of the rear suspension through a cable to an integrator which also receives signals from the front suspension through a lever system. The integrator consists of two buffer springs, a moving body, an inner tube and a center rod. The integrator computes the necessary angular movement of the headlamps and, by a lever mechanism, adjusts their attitude to maintain them level.

Two-Level Signalling System

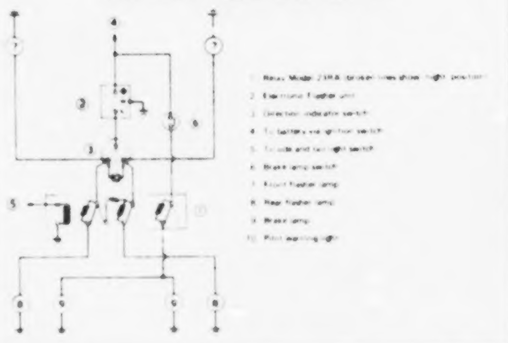

1 Relay Model 21RA (broken lines show 'night' position)
2 Electronic flasher unit
3 Direction indicator switch
4 To battery via ignition switch
5 To side and tail light switch
6 Brake lamp switch
7 Front flasher lamp
8 Rear flasher lamp
9 Brake lamp
10 Pilot warning light

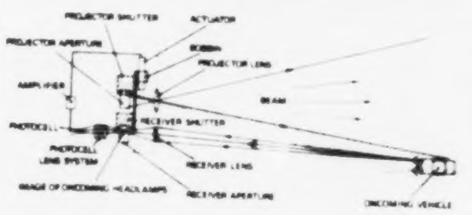
FIGURE 2

Analysis of statistics has shown that the greatest number of accidents for any given type of vehicle maneuver involves turns across the oncoming traffic. It is therefore important to signal a driver's intention in the clearest possible way. With the ambient illumination varying many orders of magnitude, as it does, between day and night conditions the use of the same intensity of illumination for signalling lamps must be a poor compromise. Two level signalling is considered to be an improvement and legislation for the compulsory fitment of such equipment to all new vehicles in the U.K. comes into force in July 1973.

In such vehicles, the switching on of the driving lights causes a relay to operate so that resistance is introduced in all signalling lamp circuits at the rear of the vehicle. Whenever these are operated under night-time conditions a reduction of glare occurs with a consequent improvement of conditions for other road users. There is no reduction in output of the front turn signal indicators for these must show up when compared with the higher intensity of the headlamps.

The variation in luminous output between day and night conditions is in the ratio of 4:1.

Diagram of Optical Principle used in Lucas Autosensa


PROJECTOR SHUTTER
ACTUATOR
PROJECTOR APERTURE
BOBBIN
PROJECTOR LENS
AMPLIFIER
BEAM
RECEIVER SHUTTER
PHOTOCELL
PHOTOCELL LENS SYSTEM
RECEIVER LENS
IMAGE OF ONCOMING HEADLAMPS
RECEIVER APERTURE
ONCOMING VEHICLE

Cut-Away View of the Lucas Autosensa

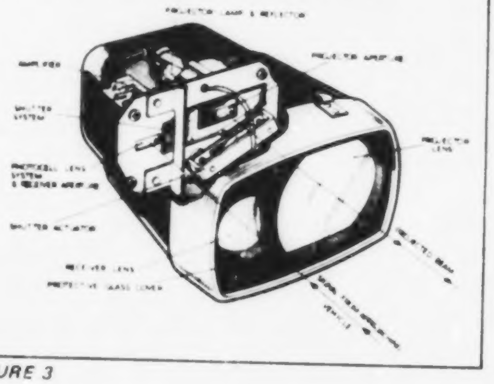

PROJECTOR LAMP & REFLECTOR
AMPLIFIER
PROJECTOR APERTURE
SHUTTER SYSTEM
PROJECTOR LENS
PHOTOCELL LENS SYSTEM & RECEIVER APERTURE
SHUTTER ACTUATOR
RECEIVER LENS
PROTECTIVE GLASS COVER
PROJECTED BEAM

FIGURE 3

Seeing distances at night in meeting and passing situations are inadequate using conventional headlamps. The automatic projector lamp has been developed with the object of providing illumination and therefore driver vision past the oncoming vehicle. It augments rather than supplants the illumination provided by the lower beams.

When there is no oncoming traffic a rectangular high intensity beam is projected, but with the approach of a vehicle from the opposite direction an image of the headlamps is formed by the receiver on the surface of a photo conductive cell. The photo cell signal is passed through an amplifier and energizes the linear actuator moving a shutter across the aperture until the shutter 'homes' on the image. Movement of the image is tracked by the shutter so that a second shutter attached to the first controls the offside edge of the beam so as not to dazzle the oncoming driver. The remainder of the beam is retained giving greatly improved visibility without handicapping the oncoming driver.

HEADLAMP CLEANING SYSTEM

Good visibility for the driver depends, not only upon the provision of good optical systems and light sources, but also upon the cleanliness of the outer surfaces through which the light must pass. Accordingly, there is a demand from the motoring public for equipment to wash and clean the headlamps. Furthermore, the Swedish Government has enacted legislation for the compulsory fitment of such equipment to new vehicles. The system fitted to the car uses a windshield wiper motor to drive the small heavily loaded wiper blades which are made to traverse the outer surfaces of the lamps. Simultaneously, water is delivered to the surfaces by an electrically operated washer. The equipment parks the blades clear of the lenses when the wash/wipe cycle is terminated. The system is capable of cleaning headlamps so that when salt, rubber and bitumen deposits from the road have reduced the luminous output below 20% of that of a fully cleaned headlamp, an 8 second cleaning operation raises the output to 90% of that of a perfectly cleaned headlamp.

FLASHER

Reference has already been made to the requirement for reduced illumination of signalling lamps under night driving conditions. The detection of a filament failure under these different electrical conditions places higher demands upon the equipment that operates the turn signalling lamps. It is also important that a closer control is maintained over the frequency of operation of these lamps and these two features, together with the ability to operate all four lamps to indicate a road hazard have been incorporated in a single electronic flasher.

The particular equipment fitted to the car is capable of operating three bulbs per side and can indicate bulb failure even when two are being dimmed. Filament failure is indicated by a doubling of the flasher frequency and it is detected by, in effect, measuring the resistance presented to the circuit during the 'off' period of the cycle.

AUTOMATIC ANTI-DAZZLE MIRROR

Although it is now some years since the automatic anti-dazzle mirror was first produced, improved knowledge and expertise in the use of semi-conductors makes this equipment a desirable item of safety equipment. A prismatic glass which is silvered for normal daylight use, has its attitude adjusted by a photo conductive cell, associated amplifier and solenoid, when glare from a following car's headlamps is detected. The changed attitude produces a secondary reflection of reduced intensity and so provides clear and comfortable vision of the following traffic. A delay is built into the circuit so that the mirror does not 'flap' as the incident light varies in intensity. A switch is provided on the lower edge of the mirror so that the driver may override the control if he so desires.

VEHICLE CONDITION MONITOR

The system is capable of indicating a variety of faults which can arise in the vehicle, by illuminating readouts and by giving audible warnings. Two displays, each indicating four conditions, are mounted one above the other behind a single window. Because four indications all occupy the same position in the window, only one of these may be illuminated at any one time, so a fault priority system must operate. Any condition in the top display may, of course, be illuminated at the same time as any condition in the bottom display. Signals are accepted from the sensors suitably distributed around the vehicle and these are processed by the signal coordinator to suppress those of lower priority and to provide the audible warning when appropriate. This warning sounds as soon as the fault occurs and automatically switches off after a few seconds. A further fault causing a change in the display will give the audible warning again. In most cases the normal condition of a sensor is indicated by the passage of current through it. Failure is indicated by interruption of this current, so that the system 'fails safe' and checks the wiring that is connected to the sensors.

RADAR

Experimental work on the use of radar equipment for headway control is currently in hand with a Q-band frequency modulated continuous wave radar as the information source. An electronic "computer" carried on the vehicle makes calculations based on "headway" and relative velocity, with respect to the leading vehicle. Brakes and throttle are then automatically adjusted to maintain a consistently safe distance. Although the system works very well under

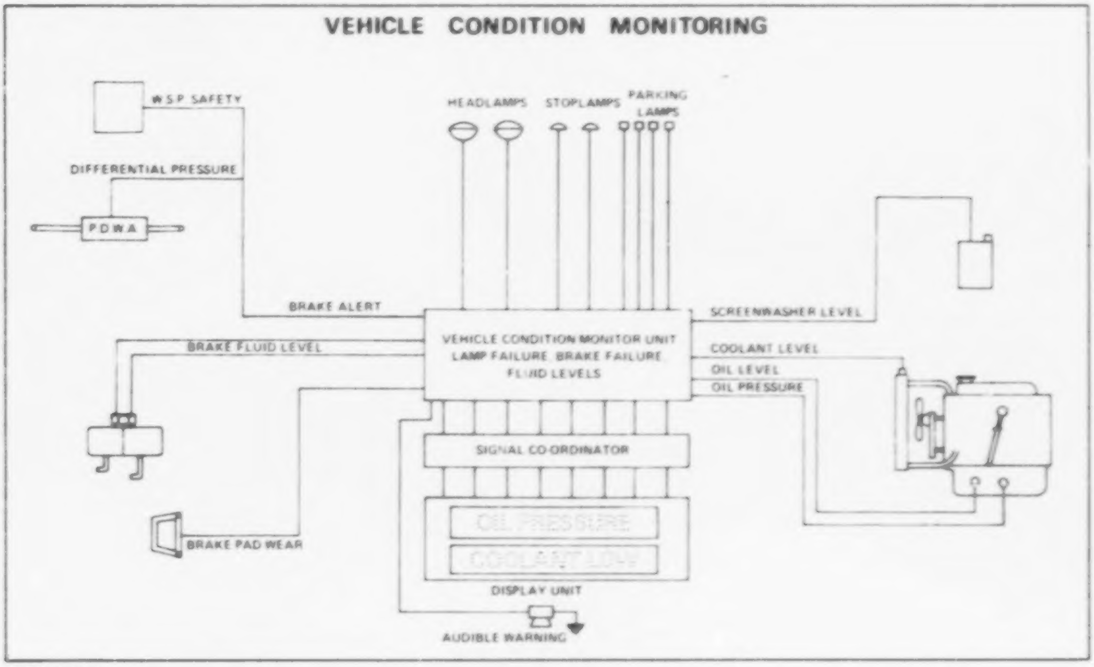

VEHICLE CONDITION MONITORING
W.S.P. SAFETY
DIFFERENTIAL PRESSURE
P D W A
BRAKE ALERT
BRAKE FLUID LEVEL
HEADLAMPS
STOPLAMPS
PARKING LAMPS
VEHICLE CONDITION MONITOR UNIT
LAMP FAILURE BRAKE FAILURE
FLUID LEVELS
SCREENWASHER LEVEL
COOLANT LEVEL
OIL LEVEL
OIL PRESSURE
SIGNAL CO-ORDINATOR
OIL PRESSURE
COOLANT LOW
DISPLAY UNIT
BRAKE PAD WEAR
AUDIBLE WARNING

FIGURE 4

test conditions the equipment is in an early stage of development and is likely to be confined to use on limited access highways. It will probably require mandatory fitment of corner reflectors on the rear of any vehicle using the highway but within such limitations it can provide a useful contribution to road and vehicle safety.

The equipment is installed on a large car which can accommodate the plumbing associated with the circuitry of the transmitter and receiver. It was not feasible to fit this to the SSV2. In production, such equipment would be redesigned so that a considerable contraction in size would take place, by the use of microstrip and printed circuit antennas.

ACTIVE RIDE CONTROL – IT'S CONTRIBUTION TO IMPROVED HANDLING

MR. WILFRED N. BAINBRIDGE, *Manager*

Product Development, The Automotive Products Group

INTRODUCTION

Conventional suspension systems are essentially passive in character in that their posture at any given moment is the collective result of those forces that have been applied since the system was last in steady state equilibrium. An active suspension system by comparison maintains an optimum posture, regardless of prior disturbances and this can be achieved only if it can call upon a power source at least as great as the power imposed by external disturbances.

Initial investigations into active suspension began at Automotive Products in 1964 by the application of a counter banking roll system to the front axle of a typical small British passenger car. The purpose of this experiment was to establish the subjective reaction of passengers to such a device, and when this was found to be generally favorable, we decided that there was a case for extending the experiment to both axles in an effort to obtain some quantitive information of the effect of such a system on cornering power.

This experiment was carried out on a Ford Lotus Cortina sports car and resulted in gains in cornering power in excess of 20%.

At this time in late 1966 the Rover Car Company became aware of the work that we were doing in this area and suggested a joint experiment on a Citroen car which was chosen because the necessary system could be more conveniently fitted to it than most other then current models. The basic intention of this experiment was to obtain correlation between theoretical computed performance and actual measured performance, and in fact an extremely satisfactory degree of correlation was obtained.

Encouraged by this result it was decided to design a system for an experimental car based on the technology thus established and most of the detailed development that has taken place since 1969 has been carried out on this vehicle.

SYSTEM REQUIREMENTS

The required characteristics aimed at for this suspension system were:

1. A low natural frequency
2. A constant attitude for the car regardless of load
3. A constant attitude for the car in roll and pitch regardless of dynamic weight transfer
4. A constant front to rear distribution of roll stiffness to provide consistent handling under all conditions
5. An optimum attitude of the tire to the ground under all conditions

THE SYSTEM

The system eventually developed is shown in Diagram 1. Essentially this system separates the aspects of ride comfort from those of ride control. The car is supported by hydro-pneumatic struts all round in place of normal road springs and shock absorbers. There is an engine driven variable delivery pump which supplies high pressure fluid to three valves. The two valves on the front of the car control the front struts in roll, pitch and height and the rear struts in roll. The single valve on the rear controls the rear struts in pitch and height. Space limitations on the experimental car initially determined the working pressure at 3,500 p.s.i. but subsequently it has been found possible to reduce the system pressure to 2,000 - 2,500 p.s.i. to be compatible with other sub-systems requiring hydraulic power.

Gas springs were chosen because of their gas law compression characteristics which give a substantially constant natural frequency over the full load range. The struts associated with them operate about a constant mean length under all conditions of load and advantage is taken of this to reduce the gas spring rate to a minimum consistent with available wheel travel.

The three servo valves controlling the car attitude in ride are high response units signalled from the mean position of the suspension relative to the body.

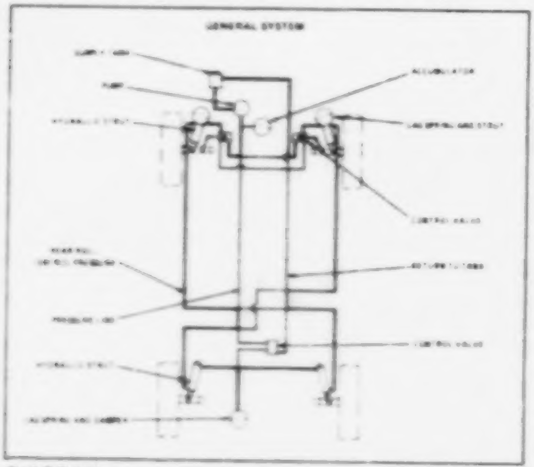


DIAGRAM 1

A schematic of a typical control valve with its associated suspension-elements is shown in Diagram 2. The three line servo valve is mechanically operated and under steady state conditions it is maintained in the central overlap position by a balance of forces produced by the offset pendulum and the spring which is attached between the pendulum and the suspension. A damper is added across the spring to provide a stabilizing velocity feedback. In effect this pendulum mass/spring/damper arrangement models the vehicle suspension.

It is easy to see from the diagram that static load change will be reacted by increasing or reducing the pressure in the suspension struts and because of the high response of the valve this reaction is very rapid indeed.

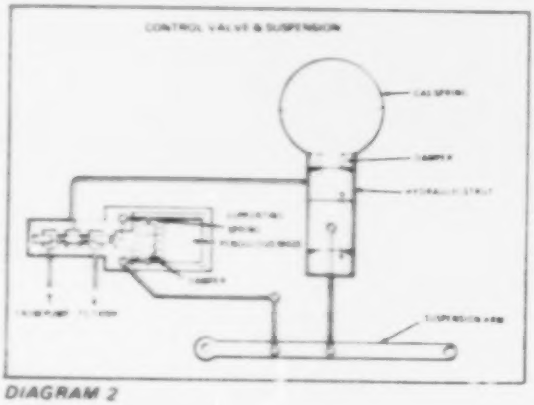


DIAGRAM 2

SYSTEM OPERATION

The dynamic performance of the system needs to be considered in relation to three types of condition.

One Wheel Bump

Still considering Diagram 2. When the wheel passes over a bump it is accelerated upwards and in doing so it produces through the suspension spring/damper a force accelerating the body upwards. The pivot of the offset pendulum moves with the body and this would leave the mass of the pendulum behind but for the input of the suspension wheel movement onto the base of the pendulum support spring. This input produces a force on the pendulum mass which accelerates it upwards at the same rate as the car body. Thus there is no movement of the valve and the suspension stiffness is simply that of the air spring. A typical response of the car to a 2 inch step change is shown in Diagram 3.

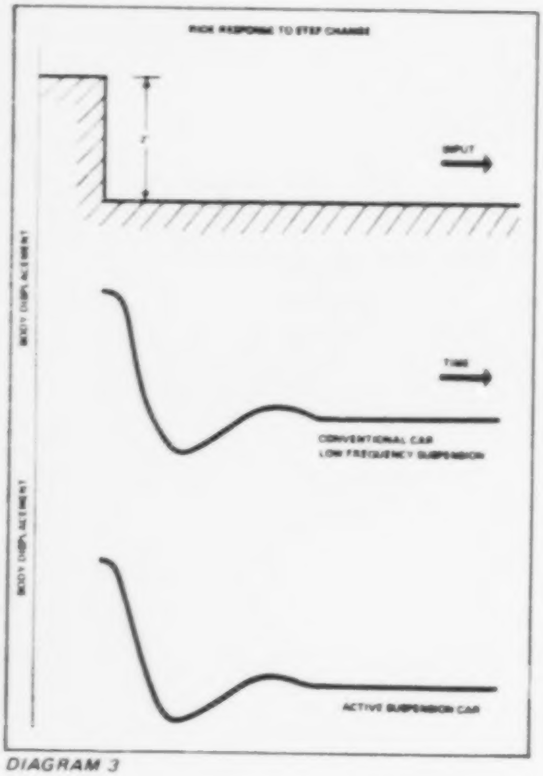


DIAGRAM 3

Cornering

Returning again to Diagram 2 the action during cornering is that the valve on the outer side of the curve reacts to the increased load on that side of the vehicle and increases the pressure in the corresponding struts to balance it in much the same way as for the static weight change. The valve on the inner side of the curve senses a reduced load and allows pressure out of the corresponding struts. In addition the pendulum has a vertical offset from its pivot and thus in conjunction with the lateral acceleration on the car gives an additional displacement to the suspension to compensate for differential tire deflection. It is obvious that this latter effect could be increased to give inward banking but our view is the gains in tire performance and lane change maneuvers, which the system gives, would then be lost.

Diagram 4 shows the roll response of a car fitted with the system compared with that of a similar standard car, when a step input is applied to the steering wheel.

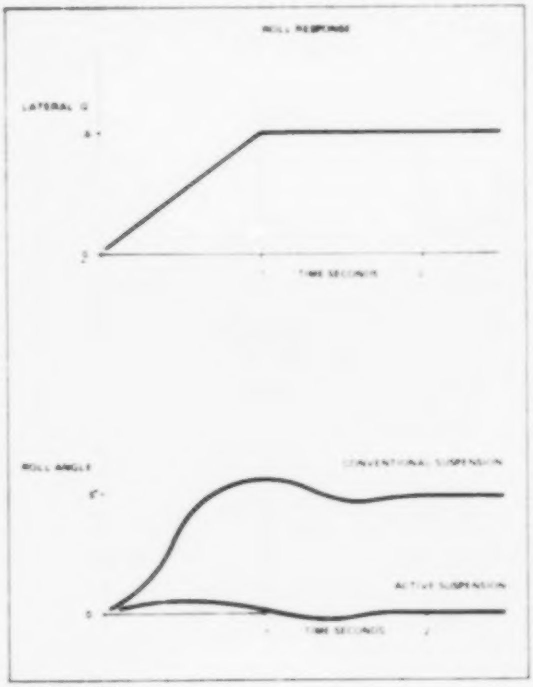


DIAGRAM 4

Diagram 5 shows the dimensions of a test chicane and listed below are the speeds at which various cars can be driven through by a standard driver without hitting the markers.

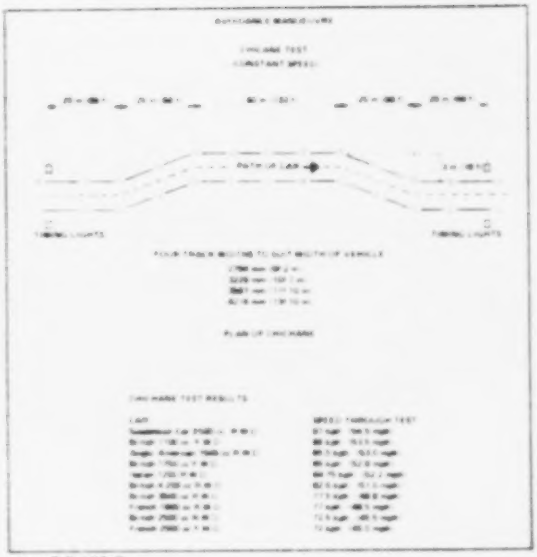


DIAGRAM 5

Pitch

The action of the system under braking or accelerating is to sense the tendency to change the body/suspension relationship and to react to keep the car in its predetermined attitude. This is again very similar to the static weight change reaction. Braking power benefits because there is no camber change at the wheels. Pitching frequencies are normally much lower than those in roll, and as the response of the system is geared to the roll requirements it is perfectly adequate to deal with the demands in pitch.

CONCLUSION

From a safety point of view the two most important gains of this active suspension are first the improved degree of control during an avoidance type of maneuver and second the large increase in cornering power. The absence of any feeling of delay or over reaction to steering wheel movements adds a new dimension to the concept of high speed controllability. Both of these gains are without impairment in the ride characteristics, indeed there are improvements also in this respect.

Other benefits which should follow from this type of system are improved tire life, increased braking performance and of course constant headlight attitude.

The system described is in principle in no way limited to applications on cars. It can offer advantages on certain types of commercial vehicle, on public transport and on military vehicles. In addition, having provided a high pressure hydraulic system for suspension purposes it makes sense to use it to power a divided line brake system, with anti-locking performances, a high pressure steering system, clutch operation or in fact any other device requiring amplification of human effort.

DEVELOPMENT AND IMPROVEMENT OF IMPACT TEST METHODS

MR. M. A. MACAULAY, *Head of Research*

Safety and Ergonomics Motor Industry Research Association

We do not make vehicles but we carry out tests for vehicle makers and also do background research on the relevance of these tests. I shall not comment on developments in vehicles but talk only about impact test methods and the relevance of these methods to the problems which they are intended to solve. Vehicle impact testing on a large scale to legal requirements is only a few years old and although the severity and complexity of the tests laid down have been increasing steadily this has been as a continuous extension of the original requirements rather than as a re-evaluation of these in the light of experience gained in service. Such a reassessment will need to be carried out before long and this paper is intended as a contribution towards it.

Testing is always a compromise between what is desirable and what is feasible. An ideal test procedure takes only the essential features of a real-life situation and incorporates these in a simple and repeatable test. In practice the requirements of realism and simplicity conflict. Sometimes they conflict badly and then, unless we are very careful, a dangerous situation arises in which the tester has to choose between doing something obviously stupid which will get him through the test or doing something obviously sensible which will fail him. Even if we surmount this there is still a further problem because it is perfectly possible to have a good test procedure, ensure that it is complied with sensibly and still do more harm than good in the real-life situation.

None of this is an excuse for not trying but it does show that it is necessary to check continuously whether the tests at present being carried out really improve the real-life situation. This is not unique to vehicle impact testing. It is always difficult to decide which are the essential aspects of a complex situation so that the assumptions underlying test procedures are often in error. The more complex the situation the less likely we are to get things just right in the first one or two attempts.

There is no doubt that we have all become much better at carrying out impact tests to the specified requirements. We ourselves now do more tests in a month than we used to do in a year five years ago and the rate is still going up. The tests are also much more reliable and much more closely controlled despite a considerable increase in complexity. Despite this there are still drawbacks to the tests as tests regardless of their relevance to the real-life situation. The main one is that they are so unrepeatable that they are extremely difficult to interpret.

This is due, at least partly, to poor definition of the test requirements. The impact conditions for the vehicle itself have been reduced in most cases to a highly simplified and stylized test which is simple enough to give repeatable results and yet realistic enough to be acceptable to most people. The requirements for the dummy occupants have not been clarified to anything like the same extent. As a result the specification of these dummies is so loose in some respects that perfectly legitimate variations in dummy construction can have larger effects than any practicable modification to the vehicle or any foreseeable change in the criteria for passing the tests. In other respects the specification is so rigid that we are hampered in using improved dummies even though we know areas in which the present specification is irrational and misleading.

A further reason for lack of repeatability is the large number of variables which are left to the tester's discretion. Vehicle makers have known for a long time that it is impossible to get repeatable results even when checking internal dimensions with a simple, static manikin unless a clearly defined, standard setting-up procedure is used. With the much more complex impact dummies such a standard procedure seems even more necessary but existing procedures are inadequate and unrealistic. This is particularly important as it seems very unlikely that dummy occupants will ever be simplified to the same extent as the vehicle impacts.

Let us now look at the next aspect of the problem of testing. How realistic is the test situation? I have chosen, almost at random, four examples to illustrate what I think are the four basic problems in getting a good test procedure. The first is that it may not be possible to get a satisfactory test to simulate a very complex situation. A case in point is vehicle rollover. I said earlier that in most cases the simplified impact of the vehicle itself is sufficiently realistic to be acceptable to most people. The basic reason is that the overall dynamics of the vehicle in real life are pretty simple. In rollover the overall dynamics are much more complicated giving much more scope for variations from test to test even in nominally identical conditions. As a result tests which are sufficiently simplified to give repeatable results are misleading, tests which are sufficiently complex to give realistic results are not repeatable and the best compromise available to date is neither a very good test nor a very good simulation. Nonetheless it may be the best that can be done.

The second problem is that in some cases we do not know what we are trying to simulate. A case in point is the neck of the dummy occupant. We know that seat belts work well in service, we know that in impact tests using seat belts dummy head decelerations are often higher than the regulations allow, we know that one of the main factors influencing these decelerations is the dummy's neck, we know how to alter the necks to get the dummy through the test. What we do not know is what neck simulation we should be aiming at and how relevant the head decelerations are to the situation anyway.

The third problem is that of misinterpreting the available evidence. It is inevitable that this will happen from time to time especially in a new area of activity which covers a number of existing disciplines so that no one is an expert. A case in point is the chest of the dummy occupant. Test results exist showing the behavior of the human chest on impact. Originally the dynamics of the chest on impact were misunderstood but I believe that they are now much better understood even though much work remains to be done. Test procedures were defined on the basis of the original misunderstanding and there they remain so that we are not allowed to make use of our improved knowledge.

The fourth problem is that there can be a divergence between passing the test and common sense. For example one of the criteria for passing the test is the deceleration of the dummy's head. In some cases it is possible to get lower decelerations by letting the dummy strike its head on the steering wheel rim but in real life this would increase the damage to the driver.

Let us now turn to the final aspect of testing. Is all this activity improving the behavior of vehicles in real accidents? So far I think we must say that we hope so but we are not quite sure and we shall not know for some time to come. We are all learning fast on this aspect as well but it takes time for evidence to accumulate, then it has to be analyzed and finally we have to decide what it means. In a complex situation this is seldom easy because so many things are inter-related and there are few simple and obvious answers. For example, in pre-legislation vehicles drivers injure their chests on the steering wheels. In post-legislation vehicles the steering wheels and columns do not move back towards the driver on impact and they collapse under load. What appears to be coming out of current accident studies is that chest injuries are reduced as was expected. But when an unrestrained driver does not hit his chest hard on the steering wheel he has to get rid of his kinetic energy in some other way and the accident studies indicate an increase in the severity of other injuries. We may still turn out to have improved the overall situation but it is not so clear cut as it looked to begin with.

I should like to end on a more cheerful note. I have dwelt on problems rather than achievements because I believe that the problems are urgent and need to be aired. It would have been more pleasant to present a paper on our achievements which have been considerable even though they all began life as a list of awkward problems rather like the ones I have just outlined. I hope that we shall overcome our present problems equally successfully but we shall not do this by pretending that they are not there.

SEAT BELT SYSTEMS FOR THE FUTURE

MR. E. NICHOL, *Technical Director*

Auto Restraint Systems Limited

INTRODUCTION

Passenger restraint systems in the form of seat belts have been in use for many years and their effectiveness in reducing loss of life and injury is a well established fact. Historically there has always been some reluctance on the part of the motorist to use them. To some extent this can be attributed to the difficulty experienced in fastening the older type belts, together with the necessity of adjustment of both the lap and shoulder belt lengths on fixed systems. On some larger vehicles, the belted-in occupant sometimes had difficulty in reaching forward to operate controls on the fascia with adequately tightened belts. This restriction of movement and the friction of the webbing on the chest of the occupants undoubtedly discouraged the usage of such systems and has prejudiced many individuals against seat belts generally.

In recent years there has been a substantial improvement in the design of seat belt systems. The adoption of the three point belt used in conjunction with a vehicle sensitive reel, facilitates single handed operation and by virtue of the fact that the reel is only locked under conditions of more than 0.3 'g', this allows the occupant some freedom of movement although the belt is always tensioned by the reel spring to eliminate slack.

In the United Kingdom the benefits of seat belts have been widely campaigned by the Transport and Road Research Laboratory. A great amount of work has been carried out by this Government Department to promote the improvement of systems, to encourage a greater usage and to establish their merit by virtue of painstaking investigation into accidents and the injuries inflicted on the vehicle occupants, both with and without the use of belts.

For some years the TRRL has been intimately involved in the development of passive seat belts and Auto Restraint Systems Limited has been commissioned to further this development under a contract to the TRRL granted during 1971.

SEAT BELT LEGISLATION

In the United Kingdom it has been a legal requirement to fit seat belts to all new cars in the front seat positions since 1967, although there is no legal requirement for the occupants to wear the belts. Certain States in Australia have introduced legislation for the compulsory wearing of seat belts and initial reports on the response to this requirement has indicated a major increase in usage up to 70%. It will be of world-wide interest to observe the longer term effects of this legislation and its influence on the reduction of road deaths and injuries.

The legislation introduced in the U.S. in 1972 aims at 100% usage of front seat belts by virtue of an audible and visual warning which is cancelled when the belts are fastened. This relatively simple system can be cheated however, by those foolish enough to do so, by leaving the belts permanently plugged in and sitting on them.

The requirements of the U.S. Government for cars manufactured after August 1973, represent a major change, not only to call for a more foolproof warning system, which precludes starting the engine unless the front seat belts are fastened, but also to insist on a limited injury severity under specific crash conditions.

A further degree of sophistication is demanded in the proposed legislation for August 1975, where one of the options is a completely passive seat belt system, calling for no conscious effort on the part of the front seat occupants to fasten their belts, coupled again with limited injury severity.

Some of the systems under current development to meet these requirements are described in this paper.

DEVELOPMENT OF SYSTEMS TO MEET THE AUGUST 1973 AMERICAN REQUIREMENTS

Seat Belt Configuration

The seat belt configuration favored for the August 1973 requirements is shown diagramatically in Figure 1. The vehicle sensitive inertia reel is mounted at the base of the "B" post, while a pivoted loop is positioned toward the top of the "B" post at the appropriate height, the belt runs from the reel through the loop and its extreme end is anchored adjacent to the reel. The buckle tongue is positioned in this portion of the belt in such a manner that when not in use it is retracted by the reel spring up to the loop, being held by friction from sliding to the floor. The buckle socket is mounted on a short length of webbing which in turn is secured to the floor in an appropriate position between and behind the front seats. Preferably the buckle is mounted on the end of a flexible steel cable so that it is correctly positioned to enable the combined shoulder and lap belt to be plugged into the buckle in a single handed operation.

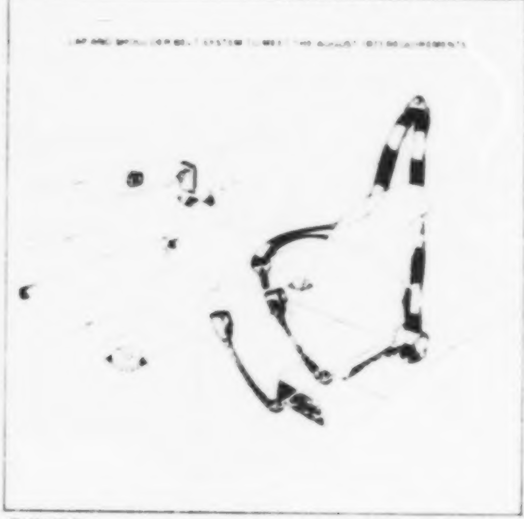


FIGURE 1

Warning System Requirements

The purpose of the regulations is to make it difficult to drive the car without the safety belts properly fastened in any of the front seat positions. To achieve this, two sensing switches are employed for each front seat, one in the seat base to detect the presence of the occupant and the second in either the buckle of the safety belt, or in the safety belt reel, to detect that the seat belt is fastened.

An electronic logic circuit is connected to the sensors, this recognizes which switch has been actuated and remembers the order in which their actuation has occurred. If the belt is left unfastened or it is fastened before the seat is occupied, the starter of the engine is rendered inoperative and an audible and visual signal is given when an attempt is made to start the engine. Should the engine be started and the belt or belts then released the warning will be given, but the operation of the engine will not be affected.

The audible and visual warning is inhibited if either the parking brake is engaged, or when the gear selector is in neutral. If an attempt is made to start the engine without any front seat passenger adequately belted, the warning is also given with the ignition key in the start position, irrespective of the transmission switch position.

Once the belt or belts have been correctly fastened and the ignition switched on, the seat sensor is rendered inoperative, to avoid the possibility of the warning being given should the occupant have raised himself off the seat momentarily or become airborne due to road surface irregularity.

To endeavor to overcome the potentially dangerous situation arising should the engine be stalled in a hazardous traffic condition with a belt unfastened, the engine starting system is arranged to be operable without interference from the belt interlock system, within a period of not more than three minutes after the engine has been stopped.

To facilitate servicing it is permissible to provide a manual switch in the engine compartment which overrides the starter protection system and allows the engine to be started without the belts being fastened. The signal from the switch must be cancelled when the engine stops, to avoid abuse.

In interpreting the regulations it appears that the facility of starting the engine without occupancy of any of the front seats is permissible, in which case the under hood switch should not be necessary. The logic circuit is capable of meeting this situation should it be deemed acceptable.

A block diagram showing the essential features of the logic circuit is given in Figure 2.

The electronic circuit is of the custom designed integrated type, giving reliability and small size. The integrated circuit is protected against malfunction owing to transient pick up, or damage due to misconnection, by virtue of the inputs being fed in via high value resistors.

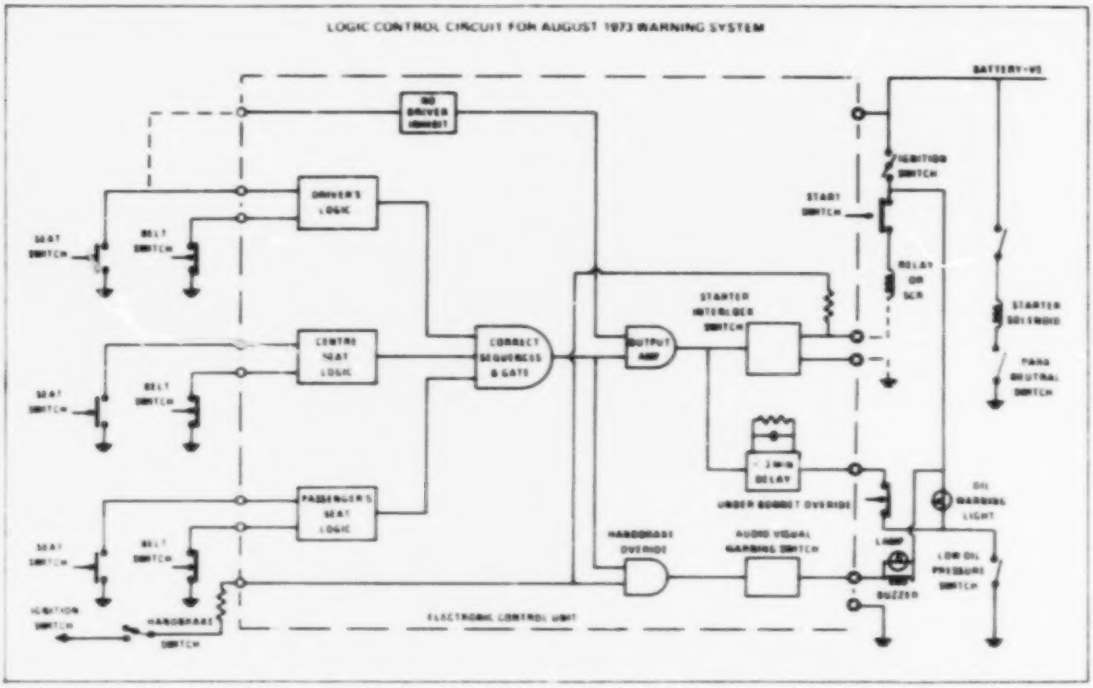

LOGIC CONTROL CIRCUIT FOR AUGUST 1973 WARNING SYSTEM
NO DRIVER INHIBIT
DRIVER'S LOGIC
SEAT SWITCH
BELT SWITCH
CENTRE SEAT LOGIC
SEAT SWITCH
BELT SWITCH
PASSENGER'S SEAT LOGIC
SEAT SWITCH
BELT SWITCH
IGNITION SWITCH
HANDBRAKE SWITCH
CORRECT SEQUENCES & GATE
OUTPUT AMP
STARTER INTERLOCK SWITCH
< 3 MIN DELAY
UNDER BONNET OVERIDE
HANDBRAKE OVERIDE
AUDIO VISUAL WARNING SWITCH
ELECTRONIC CONTROL UNIT
BATTERY +VE
IGNITION SWITCH
START SWITCH
RELAY OR SCR
STARTER SOLENOID
PARK NEUTRAL SWITCH
OIL WARNING LIGHT
LAMP
BUZZER
LOW OIL PRESSURE SWITCH

FIGURE 2

Seat Belt Injury Criteria Requirements

At the time that the original proposed American injury criteria were announced, it was not known whether seat belt systems could be developed to meet the requirements. The most difficult of these criteria to satisfy was found to be the head severity index.

Preliminary evaluation and development of seat belt system performance under crash conditions has been carried out on sleds as shown in the photograph Figure 3. In this test arrangement two dummies of similar type are tested on a two seat buck, which in turn is fixed to the test facility sled. The sled is crashed into a barrier at 30 mph, its deceleration being controlled to simulate the crash characteristics of the vehicle under consideration. The majority of this work undertaken to date has been carried out on the Motor Industry Research Association crash test facility at Lindley, in England.

It has been found generally that the characteristics of existing seat belts have not been optimized to meet these specific requirements. Development currently being pursued involves both webbing characteristics and also the use of relatively inelastic parent webbing in conjunction with additional elements acting as energy absorbers.

One of the energy absorbing elements which has already given acceptable results is in the form of "tear webbing." This webbing dissipates energy by tearing apart two conventional webbings sewn back to back.

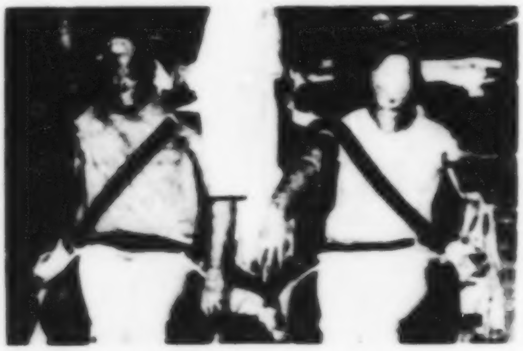


FIGURE 3

The material begins to tear at a predetermined load and then extends progressively at a substantially constant load of somewhat lower value.

Most of the development work undertaken with this material was essentially involved with passive seat belt systems, but tear webbing can also be applied to conventional seat belt layouts, where it can be conveniently disposed between the shoulder belt running loop and the anchorage point on the "B" post or roof.

Typical crash test data is given in Table I below where the results obtained with conventional seat belts are compared with a similar layout incorporating tear webbing.

Table I

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

It will be seen that the use of tear webbing has given head severity index values substantially less than 1000 on the old method of calculation. The recalculated values based on the revised method of calculation given in FMVSS No. 208, Docket 69-7, Notice 17, results in substantially lower figures. Other critical data, including chest acceleration, shoulder belt load and forward head movement satisfy the requirements, the latter obviously dependent on the space available in any particular vehicle. A typical example is given in Figure 4, where the sled test dummy position is shown superimposed in an Austin 'Mini' car.

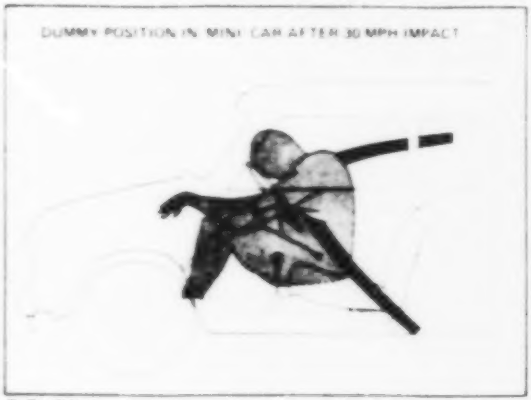


FIGURE 4

Actual vehicle crash testing has been completed with similar tear webbing energy absorbers, giving values as indicated in Table II.

The revised Severity Index criteria will permit use of a higher load tear webbing which should result in reduced forward head movement. Development with this form of energy absorber is continuing. Both static and dynamic test of this tear webbing has shown it to give consistent performance and there is every confidence that the material is of adequate reliability for this critical application.

RESEARCH INTO PASSIVE SEAT BELT SYSTEMS TO SATISFY THE AUGUST 1975 AMERICAN REQUIREMENTS

The purpose of a passive seat belt system is to protect the car occupant without requiring him to take any action to protect himself.

To achieve this the seat belts must be automatically deployed in an acceptable manner around the passenger after he has occupied his normal seating attitude in the vehicle. Preferably there should be no need for the occupant to adjust the belt or assist its movement. During deployment the belt should not disarrange the individual's clothing or exert any undue pressure on the body.

The action of such a system must be reasonably rapid and quiet so as to avoid irritation and there should preferably be a means of inhibiting the action should the car occupants wish to occupy their seats when not motoring.

A wide variety of methods of achieving passive belt deployment has been considered, a number of which are described below.

Door Mounted Reel with Single Shoulder Strap, Combined with a Knee Restraint

This layout offers a low cost solution. A belt sensitive reel is mounted in the lower rear corner of the front door, the shoulder belt runs off the reel

TABLE II

Barrier Crash Tests at 30 mph. Dummy – Alderson 50 percentile male

Vehicle	Deceleration	Old Severity Index	Forward Head Movement inches
Sports Car	87g peak	1012	19.0
Sports Sedan	75g peak	911	22.5

vertically to a loop on the upper rear edge of the door and then diagonally across to a floor mounting between the front seats. It is necessary for the passenger to push the belt forward on taking up position in the seat. When the door is closed the excess webbing is wound on to the reel. In order to give easier access, the reel is locked when the door is fully opened thus relieving the tension in the belt. On re-entering, the passenger does not have to push the belt forward against any spring load from the reel. As the door is closed, however, the reel is freed at a suitable door angle thus tensioning the belt around the body.

A single shoulder belt of this type necessitates the use of a knee restraint to avoid "submarining." This takes the form of an energy absorbing device designed to limit femur load to an acceptable level, generally considered to be of the order of 900 lbs.

As a refinement of this system, to give easier access and egress, a latch can be provided adjacent to the "A" post, at instrument panel height. This latch is exposed when the ignition is off. The passenger can manually push the belt forward and loop it on to the latch. On re-entry the latch withdraws when the ignition is switched on, allowing the belt to assume its normal position around the body.

This system has been developed and patented by the Transport and Road Research Laboratory in the United Kingdom. Figure 5 shows a diagram illustrating the system.

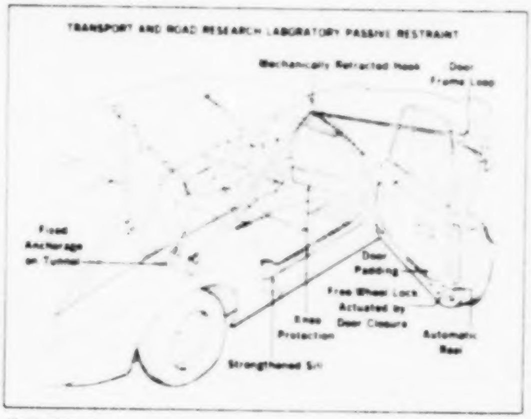

TRANSPORT AND ROAD RESEARCH LABORATORY PASSIVE RESTRAINT
Mechanically Retracted Hook
Door Frame Loop
Fixed Anchorage on Tunnel
Door Padding
Free Wheel Lock Actuated by Door Closure
Knee Protection
Automatic Reel
Strengthened Sill

FIGURE 5

Lap and Shoulder Belt Combination with Telescopic Swinging Arm

A diagram of this system is shown in Figure 6. The belts are mounted at two points on the rear edge of the front door and at the vehicle sensitive inertia reel which is situated between the front seats. A motorized swinging arm is also positioned between the front seats. The end of this arm carries a loop through which the belt passes, although no load is taken by the loop or arm in normal operation.

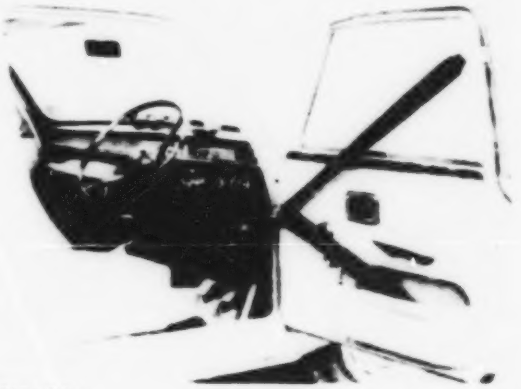


FIGURE 6

When the door is opened prior to entry, the arm swings up and over carrying the lap portion of the belt under the steering wheel and forward toward the scuttle. The belts on the door attachments also move forward to allow passenger access. A certain amount of webbing is drawn off the vehicle sensitive inertia reel as the door is opened. Relatively clear access is provided and when the door is shut the arm moves back and the belt is drawn automatically onto the body of the occupant under the influence of the spring in the reel.

On certain vehicle layouts the space between the steering wheel and the knees of the driver is very limited and to improve the operation in vehicles of this type, the arm is capable of extending either while it is swinging or subsequently at the extreme limit of its travel. The load exerted by the belt on the door is transferred from the door frame to the "B" post by a suitable latch.

An alternative to this system has been developed where space precludes the installation of the arm and its operating mechanism. In this case the layout of the belt is identical but it is pulled forward toward the scuttle by means of a motor driven cord. The cord pulls the belt from the inertia reel, situated between the seats, towards the scuttle and at the same time it is lifted upwards off the passenger's knees. The motor and its associated pulley and limit switches may be positioned in the engine compartment. Entry and egress conditions are similar.

Lap and Shoulder Belt Combination with Door Track and Control Cord Operation

One of the criticisms that can be directed at the systems already described is the difficulty in cases where the door can only be marginally opened to allow the passenger to squeeze in or out, as might be experienced in a car park. The shoulder and waist belts in these circumstances partially restrict entry and must be pushed forward slightly. By means of a motorized track in the door the belt attached to the rear base of the door can be directed forward and upward giving clear access with the door fully or partially open. Simultaneously the belt is drawn forward at the center by the cord (or alternatively by a motorized swinging arm).

The belts attached to the rear edge of the door tend to close it due to the force exerted by the retraction effort from the reel. With the door track system, however, the force tending to close the door is minimized, due to the fact that the belt load is applied at a much reduced radius relative to the door hinge axis.

A photograph showing this system applied to a small four door car is shown in Figure 7.

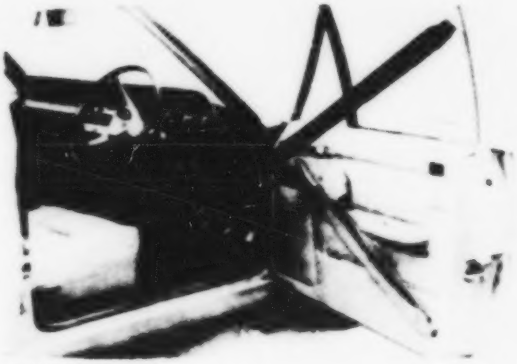


FIGURE 7

SYSTEM DETAILS

Retractor Reel Requirements

The retractor reel is of the vehicle sensitive type, but differs considerably from the normal design hitherto used in the shoulder anchorage location. Of necessity it must be more robust to withstand higher loads. Furthermore it must be able to resist these loads when there is a considerable amount of webbing wound onto the reel. It operates in reverse mode to the normal retractor reel in that the latter is only fully loaded when there is relatively little webbing wound onto it. With the new reel, unacceptable wind-up effects can occur if appropriate precautions are not taken by increasing the base diameter of the reel.

It is necessary also to control the locking 'g' levels of the reel much more accurately than hitherto. Parking on a hill can cause problems with a passive system which would not occur with a conventional seat belt, as inadvertent locking of the reel under these conditions could be readily overcome by unfastening the buckle. As the usage of a buckle is contrary to the passive principle it is of course necessary to ensure that locking of the reel on steep hills does not take place. Conversely it is necessary also to ensure that the locking does take place sufficiently early to protect occupants during conditions of severe braking.

It has been found that the tension characteristics of the new reel require considerable modification. This arises because the reel is, in effect, called upon to supply tension in two sections of the belt in parallel and thus approximately twice the normal tension is required. Furthermore, with the new reel the webbing is fully wound when the seat belts are in use, and this of course corresponds with the retractor spring being in a condition of minimum wind-up. As the actuating mechanism of the seat belt has to operate against the tension characteristics of the reel, it has been necessary to develop special means of minimizing the load on the mechanism. Naturally the tension tends to increase under these conditions, because of reduction in effective diameter of the reel due to unwinding, combined with the increase in torque due to spring wind-up. Current development is towards the ideal of a reduction in belt tension as the webbing is wound off the reel.

Choice of Motive Power

In the work on initial prototypes, it was decided to use an electric motor with suitable gearing to provide the motive power. This was done primarily to achieve speedy initial results by placing reliance on an existing "in-house" experience of automotive window lift application work. This decision was reconsidered at a later stage, against the criteria of operating time, basic energy requirement, and mechanical efficiencies. It was decided that the operating time should lie within the limits of 1 to 2 seconds. This was governed by potential impatience of the occupant balanced against the possibility of alarm arising due to a very rapid acting mechanism. The energy output requirement is defined by the reel load characteristics previously mentioned, together with the geometry of the installation. A study of these factors, coupled with realistic mechanical efficiency assumptions, enables a power output requirement to be established.

Considerations of other means of powering the system, such as vacuum operation or a direct mechanical linkage to a door opening, indicated that the electrical approach appeared to be the most suitable.

Anchorage Point Integrity and Adjustability

In mounting the seat belt anchorages on the rear edge of the door, it will be apparent that special attention will be required to the strength of the system. In particular, attention has been given to the upper anchorage, and designs have been developed which depend on interlocking with the "B" post structure. In effect the loads in most cases are transferred back directly to the conventional seat belt anchorage mounting point.

A special problem arises in the case of smaller children where the position of the diagonal portion of the seat belt is often too high, tending to cross the face or neck. It was, therefore, deemed desirable to develop an adjustable shoulder anchorage. The facility for adjustment in this manner also provides advantages in respect of the comfort of adults of different sizes. Details of this adjustment facility are shown in Figure 8.

FIGURE 8

Emergency Belt Release

It has been explained that the characteristics of the inertia sensing mechanism in the reel are tailored in such a manner that the reel does not lock even when the vehicle is positioned on severe gradients. It is, however, possible that abnormal vehicle attitudes may be experienced due to accident or other conditions. In these circumstances the inertia sensing mechanism would lock the reel, and because of the attachment of the other ends of the webbing to the door, the egress of the occupants would be prevented. To cover such a contingency, prototype installations have been equipped with a modification of a normal seat belt buckle in the lower door anchorage point. However, attention on second generation systems is being given to developing means of releasing the reel locking mechanism itself. It is reasonable to suppose that these means of emergency release should be capable of actuation by rescuers from outside the vehicle in the eventuality of the occupants being unconscious. This raises problems of a concept of an external release which is obvious in function and at the same time compatible with styling concepts.

Control Circuits

The operation of the seat belt system has hitherto been automatically linked to the door opening by means of a switch, such as is normally provided for the courtesy lights. This has been found to work very well in practice, but there are certain conditions under which it is desirable to achieve the manual override of this automatic operation. Situations calling for this facility might for instance include the desirability of achieving additional freedom of movement when taking refreshments within a parked car. Another would be the entry of a passenger into a vehicle carrying a small infant. A push button system is provided to achieve this facility and has been designed to be "fail safe" in that the belts are automatically applied when the car is driven even if the appropriate push button is inadvertently not depressed.

The systems are protected by current overload switches to prevent damage to the motors in the event of the mechanisms being stalled.

In the case of the cord actuated system, protection switches are included to obviate damage should interference with the cords accidentally or deliberately occur.

PASSIVE SEAT BELT INJURY CRITERIA

Injury criteria requirements have been discussed in relation to conventional seat belt systems earlier in this paper. Identical requirements are demanded in respect of passive seat belts.

Energy Absorbing Systems

As previously stated, the investigation of the characteristics of tear webbing was initiated on passive seat belt layouts, where it is generally possible to accommodate the tear webbing in the shoulder belt portion of the belt adjacent to the shoulder mounting point.

Examination of Figure 3 reveals the tear webbing which is white in the shoulder belt portion of the parent belt, which is itself black. The tear webbing is stitched to the parent webbing in such a manner that a loop of the latter is left in parallel with the tear webbing. When the tear webbing "gives" and absorbs energy it is important to have an adequate length of the material to avoid complete separation as this would then bring the parent webbing loop under load and possibly initiate an increased rate of deceleration of the body.

Experiments have been carried out on tear webbings with rating from 800 to 1500 lbs., and over a range of length from 6 inches to 12 inches. Further evaluation is continuing with lower extension parent webbings.

Development work with energy absorbing parent webbing is also being undertaken. In this case the energy is absorbed by the deformation of the webbing itself which results in permanent extension. As would be anticipated, those sections of the belt which do not contact the body are subject to higher load, and conversely, the length of belt in contact with the body is loaded to a lesser extent by virtue of the friction between the webbing and the passenger's clothing. Satisfactory test results have been achieved in configurations which give a relatively long length of free webbing.

Other forms of metal deforming energy absorbers, reel clutches etc., are also under investigation.

Testing Techniques

Most of the test work reported has been carried out at 30 mph. It has been found essential to ensure as far as possible that the condition of the dummies employed is consistent, in particular the neck condition can seriously influence the head acceleration criteria. Identical test runs, in which two dummies were tested on the same sled simultaneously have resulted in widely different head severity values, although chest deceleration and belt loads were comparable. This has emphasized the necessity of checking the calibration of the dummy neck between each test run.

The condition of the seat has also been found to affect results and wherever possible the seat should be renewed or at least reconditioned regularly to eliminate a further variable.

Characteristics of the "Ideal" Passive Belt Material

The conclusions drawn from tests completed to date point to the following requirements:

1. The belts should be as tight as is practicable at the time of impact. This ensures that there is no forward movement of the occupant relative to the vehicle during the crush period, which results in appreciable "ride down" energy dissipation before the energy absorbing device comes into action.
2. The shoulder portion of the belt should initially have a low extension but should then yield and continue to absorb energy at a relatively constant load. A typical dynamic loading curve for tear webbing is given in Figure 9.

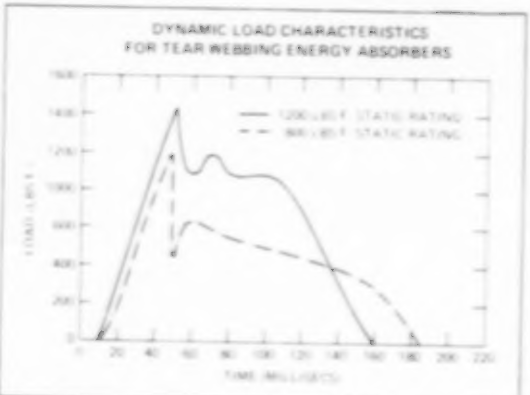


FIGURE 9

3. For a given vehicle installation, the energy absorbing device should be designed to take advantage of the maximum forward movement of the head and upper torso.
4. Use of a low extension parent webbing tends to reduce rebound and neck whip of the occupant.

CONCLUSIONS

A reliable and relatively foolproof electronic warning system can be provided to meet the August 1973 requirements. When the system is used correctly the warning is never heard and recent additions to the specification should eliminate certain possible hazards and avoid problems during servicing.

By the use of energy absorbing devices the injury severity criteria can be met with combined lap and shoulder belt configurations. The recent change in the American method of calculation of the head severity index appears to reduce the original figures by 20 to 30%.

The development work on passive belts which has already been completed indicates that systems can be devised which are reasonably acceptable to the car driver and passengers in terms of ease of entry and exit, method of actuation and subsequent comfort in use. The presence of the belt system in the vehicle may impose some limitations on the occupants in such matters as access to the driver's seat from the nearside, although this is already impracticable in many European cars. Further refinement of such systems is being pursued, together with the development of energy absorbing media to reduce maximum head deceleration and hence injury severity values to conform with the values required by the American Authorities.

As an alternative to the air bag the passive seat belt offers certain advantages. It restrains the occupants in many conditions of deceleration. Its protection in conditions of roll over is possibly superior to that offered by the air bag and in cases of secondary impact the occupant is still restrained.

TRRL/BRITISH LEYLAND EXPERIMENTAL SAFETY SUB-SYSTEM CONTRACTS

MR. P.M. FINCH, *Manager*

Test and Development Body and Assembly Division, British Leyland (Austin Morris) Limited

INTRODUCTION

As a result of negotiations between the British Government's Transport and Road Research Laboratories and British Leyland Motor Corporation, the latter have recently undertaken a number of safety projects based on the TRRL's sub-system approach to the ESV concept.

Work began on four of the projects at the end of March, the fifth is due to start at the end of this month and a sixth is under negotiation.

In all we plan to expend approximately 75 man years in development time on the combined projects, with target dates varying between 1½ and 2½ years.

The main objectives have been formulated by the Transport and Road Research Laboratory based on their analysis of road accidents and injuries in the United Kingdom. Although conceived as separate sub-systems we shall of course take into account the inter-relationship of one project to another during the development program.

In addition to associated safety features the projects will be studied with respect to ergonomics, consumer acceptance, availability of materials, cost effectiveness and feasibility with respect to mass production.

Injury patterns and other biomechanical data, required for the establishment of test criteria, will be provided by the Transport and Road Research Laboratories from their analysis of injury and accident situations.

In all but one project the development work will be based on the 1.8 rear wheel drive Morris "Marina", with a laden weight, inclusive of 2 dummies of 2385 lb. Where relevant we shall consider both the 4 and 2 door versions.

Our brief then is to develop, for each project, one or more fully tested prototypes suitable for quantity production, indicating where possible the benefits likely to be derived from their partial or complete adoption, together with a consideration of their cost effectiveness.

Briefly the project proposals are as follows:

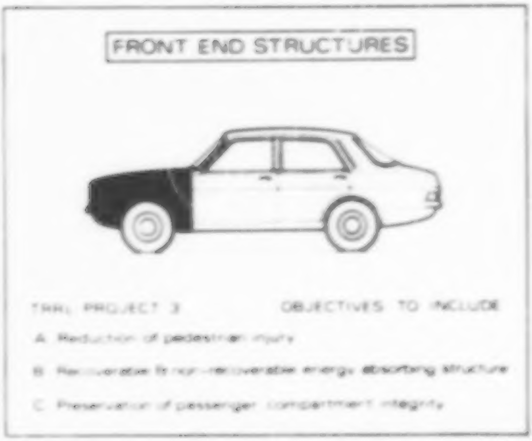

FRONT END STRUCTURES
TRRL PROJECT 3
OBJECTIVES TO INCLUDE
A. Reduction of pedestrian injury
B. Recoverable & non-recoverable energy absorbing structure
C. Preservation of passenger compartment integrity

FIGURE 1

We are committed to carry out a series of investigations into various aspects of safety in frontal impacts. The following will be considered:

1. **Pedestrian Impact**
   In the United Kingdom approximately 24% of injury producing accidents involve pedestrians. Of these, many are at a comparatively low speed, yet still result in serious leg injuries as a consequence of bumper impact. Our aim therefore is to improve the location, shape and energy absorbing properties of the bumper face with respect to this problem.
2. **Vehicle to Vehicle Energy Absorbing System**
   Here the objective is to investigate the reduction of low speed vehicle damage, using various forms of recoverable and non-recoverable energy absorbing systems. Under this heading we shall also

consider the development of a replaceable front structure in an effort to reduce repair costs.

3 **Aggressivity**

Here we are concerned with a reduction in the aggressivity of the bumper system particularly when involved in side collisions with other vehicles.

4 **Occupant Protection**

Finally, for high speed collisions we shall concentrate on a reduction in passenger compartment intrusion and occupant compartment decelerations.

Although we plan to conduct barrier impacts at 50 mph at all stages, our main design effort will be expended in developing a survivable structure for around 40 mph impacts. According to Dr. Murry Mackay's study of accidents on British roads, approximately 80% of frontal vehicle impacts producing occupant injuries involve vehicles crashing at speeds which result in structural deformation equivalent to 25 mph barrier tests or lower (Figure 2). Increasing the equivalent barrier speed by 60% to 40 mph covers 95% of such accidents. Currently vehicle legislation is centered around 30 mph barrier impacts. At this speed the kinetic energy of the Morris "Marina" is around 72,000 lb. ft.; at 40 mph this will increase by 78% to 128,000 lb. ft., and at 50 mph by 178% to 200,000 lb. ft. (Figure 3).

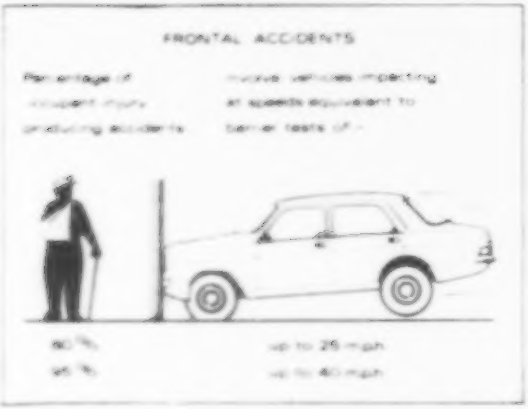

FRONTAL ACCIDENTS
Percentage of occupant injury producing accidents
involve vehicles impacting at speeds equivalent to barrier tests of -
80 %
95 %
up to 25 mph
up to 40 mph

FIGURE 2

In other words, to cover that part of the remaining 5% of British frontal collisions that are equivalent to barrier impacts between 40 and 50 mph, we must design the structure to absorb up to 56% more kinetic energy than is required to cover the 95% which does not exceed the 40 mph barrier equivalent.

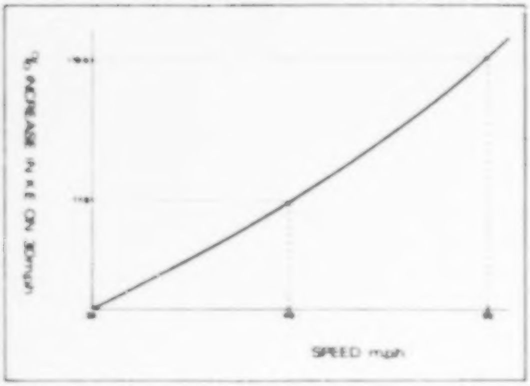


FIGURE 3

It will of course be appreciated that the 40 mph barrier test reproduces the damage resulting from two like vehicles crashing head on with a closing speed of 80 mph. So that the barrier test is in fact more severe than at first appears.

Coupled with the problem of maintaining occupant survival space is the need to control the passenger compartment decelerations to a tolerable level.

To achieve this will require a considerable increase in the size, weight and cost of the vehicle; we consider therefore that we should be prepared, if necessary, to accept a lower survival impact speed as a first stage in the development of the mass production Safety Vehicle.

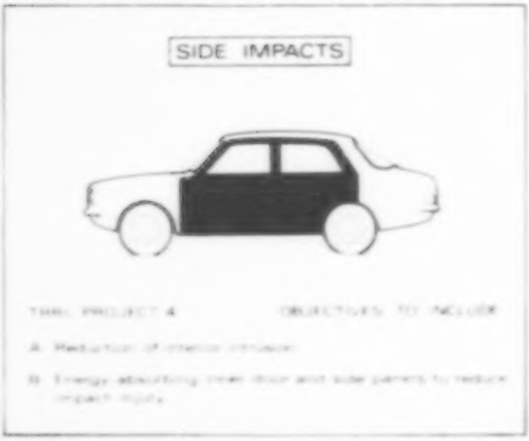

SIDE IMPACTS
PROJECT 4
OBJECTIVES TO INCLUDE
A. Reduction of interior intrusion
B. Energy absorbing inner door and side panels to reduce impact injury.

FIGURE 4

In the United Kingdom, vehicle-to-vehicle side impacts and single vehicle side impacts into roadside obstacles, account for 22% of injury-producing accidents. This project is concerned with the reduction of these injuries, which tend to fall into two categories.

1. Injury due to crushing the occupant by the intrusion of the side structure.
2. Injury due to secondary impact with the internal structure.

The problem therefore is to increase the stiffness of the doors and side structure in order to limit the intrusion, and to provide an energy absorbing interior to reduce the impact forces imposed upon the occupants.

During impact tests involving both pole and mobile barrier, the occupant injuries will be evaluated using a dummy developed by **TRRL** and equipped with load cells designed to measure lateral forces on the shoulder, ribs and hip in addition to accelerometers measuring the head, thorax and hip accelerations.

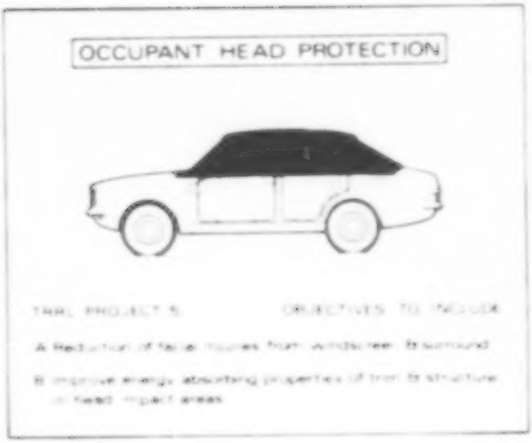

OCCUPANT HEAD PROTECTION
TRRL PROJECT 5
OBJECTIVES TO INCLUDE
A Reduction of facial injuries from windscreen & surround
B Improve energy absorbing properties of trim & structure in head impact areas

FIGURE 5

In automobile accidents head injuries occur with greater frequency than other forms of serious trauma. This particular project has been directed at the development of the interior of the occupant compartment to mitigate such injuries.

To this end we have been set two main problems:

1. Aimed at a reduction in the severity of head injuries in general by means of modified trim and structural members. However, it is recognized that a compromise will be necessary with respect to driver vision and roll-over requirements.
2. A reduction in facial injuries due to impact with the windshield surround.

This project is concerned primarily with the protection of the lower limbs during frontal impacts, in particular the knees, femur, hip and pelvis.

As with the previous project our major concern will be for the front seat occupants as being those most likely to sustain the more severe injuries, and being most frequently involved in accident situations.

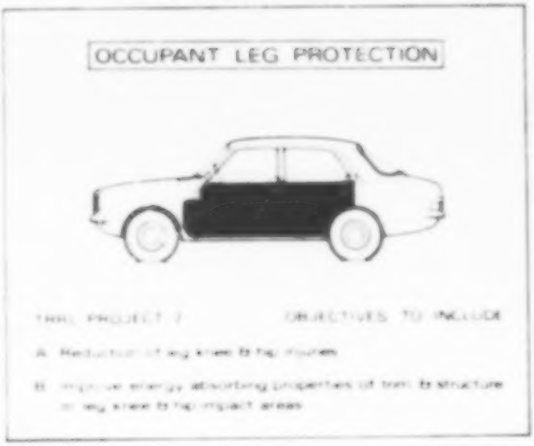

OCCUPANT LEG PROTECTION
TRRL PROJECT 7
OBJECTIVES TO INCLUDE
A Reduction of leg knee & hip injuries
B Improve energy absorbing properties of trim & structure in leg knee & hip impact areas

FIGURE 6

From the **TRRL**'s analysis of current injuries and a study of dummy kinematics during vehicle sled tests, we aim to design the interior structure and trim to absorb a significant amount of the occupant kinetic energy within tolerable levels, through the knee, femur and hip complex.

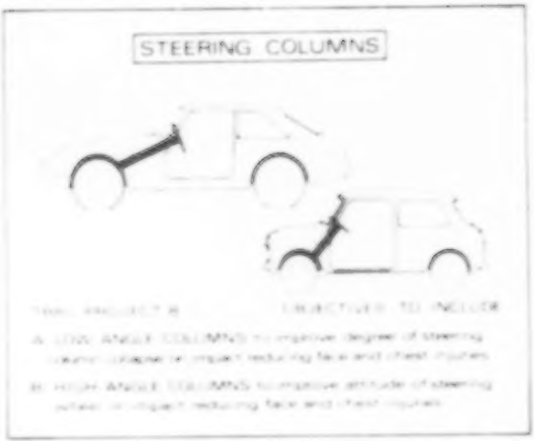

STEERING COLUMNS
TRRL PROJECT 8
OBJECTIVES TO INCLUDE
A LOW ANGLE COLUMNS to improve degree of steering column collapse on impact reducing face and chest injuries
B HIGH ANGLE COLUMNS to improve attitude of steering wheel on impact reducing face and chest injuries

FIGURE 7

In Europe steering column systems fall into two main categories, i.e.

1. High rake systems — such as fitted to the British Leyland 'Mini'.
2. Low rake systems — such as fitted to sports cars.

Although both systems meet current legislation for impact crashworthiness, analysis has revealed that where injury does occur, the two systems produce different injury patterns. The high rake systems produce injuries concentrated around the face and upper thorax, with the low rake systems resulting in injuries to the lower thorax and abdomen.

This project will endeavor to develop both systems to improve their performance beyond that which has been achieved by the introduction of current energy-absorbing systems.

During the development the systems will be evaluated mainly by means of sled impact tests using the MIRA/OGLE dummy, modified to measure rib cage loads and deflections and facial injuries in addition to the accelerations.

For the high rake system development we shall utilize the British Leyland "Mini" and for the low rake a MGB sports.

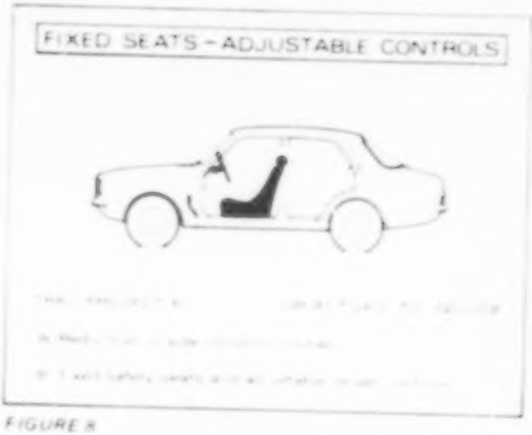


FIGURE 8

This particular project is still under negotiation with the Government. It is allied to the Side Intrusion Project No. 4, as its ultimate aim is the maximum protection of occupants from side impacts.

It is recognized that in addition to strengthening the doors and side structure it may be necessary to brace both side panel assemblies together in order to prevent their overall collapse.

One approach is to design this brace as a fixed seat structure. This concept offers other advantages, such as the optimum location of the occupants relative to the restraint system and interior structure together with the possibility of offering a degree of anti-chair protection against impacts and intrusion in general.

To accommodate the differing sizes of the driving population it will therefore be necessary to provide for adjustable hand and foot controls.

GENERAL

As mentioned previously the projects have been planned for completion within 20 to 30 months.

The next slide (Figure 9) shows, in a simplified form, a typical progress plan and indicates the main development phases. Each project begins with an evaluation of the performance of current designs in

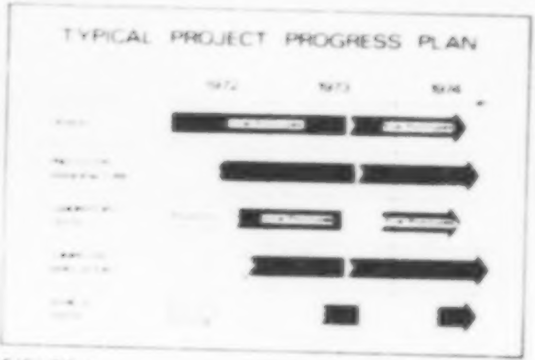


FIGURE 9

the required impact situation. At the same time computer simulation techniques are utilized to help determine design parameters and the effects of various modifications (Figures 10a, 10b and 10c).

During this initial stage the design, and later, the manufacture, of the first phase prototypes

FIGURE 10a

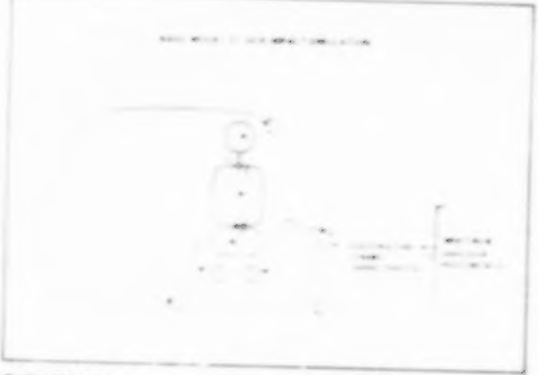


FIGURE 10b

commences. The performance of the various items and assemblies will then be evaluated and the whole procedure recycled to the degree necessary to establish the final prototype designs.

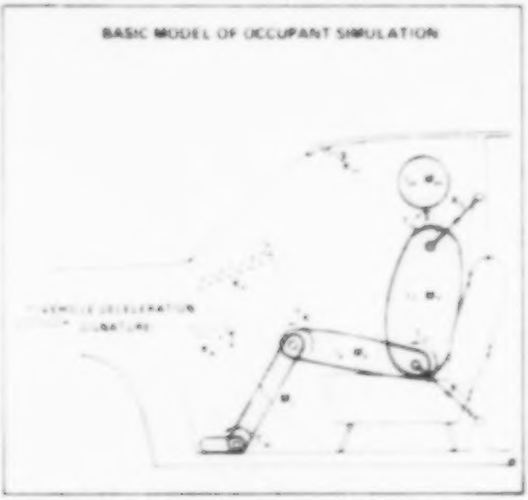

BASIC MODEL OF OCCUPANT SIMULATION
VEHICLE DECELERATION SIGNATURE

FIGURE 10

OCCUPANT PROTECTION IN SIDE IMPACTS

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Ford Motor Company of Britain

INTRODUCTION

The special problems associated with improved occupant protection in side impacts are well known. By comparison with frontal impacts, the door and side structure of cars offer only limited space in which to provide structural strength and energy absorption. It is also possible for the occupant to be closer to the point of impact than in any other type of accident, except, perhaps, rollover. It should be noted that this applies largely to those occupants on the impact side of the vehicle, for whom seat belts are ineffective. In contrast, a lap and diagonally belted occupant on the far side from impact is fairly well protected, and the universal wearing of seat belts would effect an important reduction in injuries from side impacts.

In terms of overall statistics, Figure 1 shows that side impacts constitute almost 30% of all injury-producing accidents[1] and Figure 2 shows that more than half of these are vehicle to vehicle impacts.[2] It can also be seen from this figure that the breakdown of fatal and serious injuries is very similar to the breakdown of accidents. The greatest potential gain, therefore, lies in reducing the effects of car to car impacts. This approach is also the most cost effective, since it is even more difficult to mitigate the effects of truck and fixed object impacts.

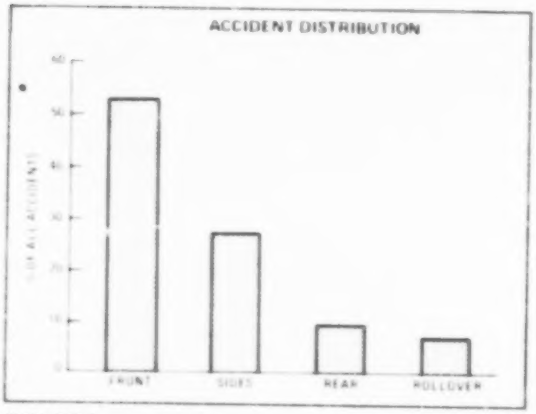

FIGURE 1

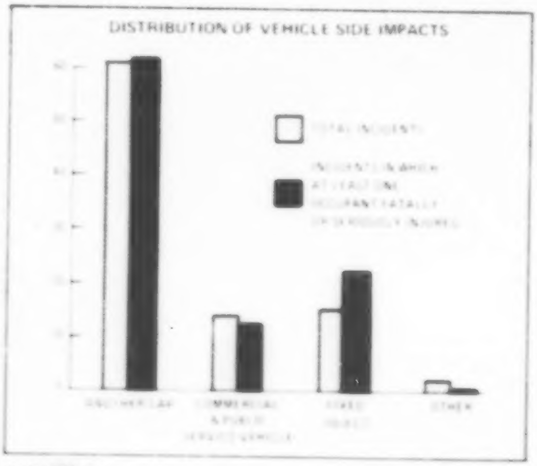

FIGURE 2

SIDE STIFFNESS AND INTERIOR PADDING

Occupant protection in side impacts is dependent on both the form of restraint employed and the vehicle structural strength. For the occupant on the impact side, the short distance between occupant and impact renders ineffective most of the systems currently used for protection in frontal impacts. Seat belts cannot offer enough lateral restraint to head and torso, and current air bag systems are too slow, both in sensing the impact and inflating the bag. The most effective type of restraint is therefore a form of energy absorbing padding, which, while technically possible, has the disadvantage of permanently taking up space inside the car. This space may have to be paid for in reduced occupant comfort. The alternative is an undesirable increase in the overall widths of cars on our already crowded roads. Exactly how much space will be required is at this stage uncertain, because of limited human tolerance data on side impacts. American studies have indicated that lateral tolerance limits may be much lower than longitudinal ones.

The structural requirements are even more difficult to accurately define. While strengthening the vehicle side may seem to be an obvious choice, it can be over-rated. As a general trend it is clearly advantageous, but in those cases where the vehicle slides bodily into a fixed object, the increased side strength brings no benefit, and can in some instances be harmful in increasing the decelerations of the undeformed parts of the vehicle. In cases where a vehicle is hit fair and square in the side, as in Figure 3, the bullet car initially penetrates the target car at the impact velocity, but the strength and inertia of the target car gradually slow it down until a common velocity is reached. During this phase, the deforming side of the target car is effectively moving towards the occupants at the speed of the bullet car. The effect of increased stiffening is to reduce the time and penetration which occur prior to common velocity. This in turn will reduce the velocity of impact of an occupant with the interior if it occurs at this stage. However, no amount of stiffening will reduce the common velocity, and the impact velocity of an unrestrained passenger can never be very much lower than this velocity.

The important point is that side strength should really be considered in conjunction with energy absorbing padding if optimum protection is to be given in really severe impacts. Present efforts should continue to be directed at doors, locks and hinges which, although they may deform, do not actually fail. This can go a long way to reducing dangerous intrusions and to increasing the tendency for cars to glance apart at the more acute angles of impact. It is also a vital step in reducing the incidence of occupant ejection.

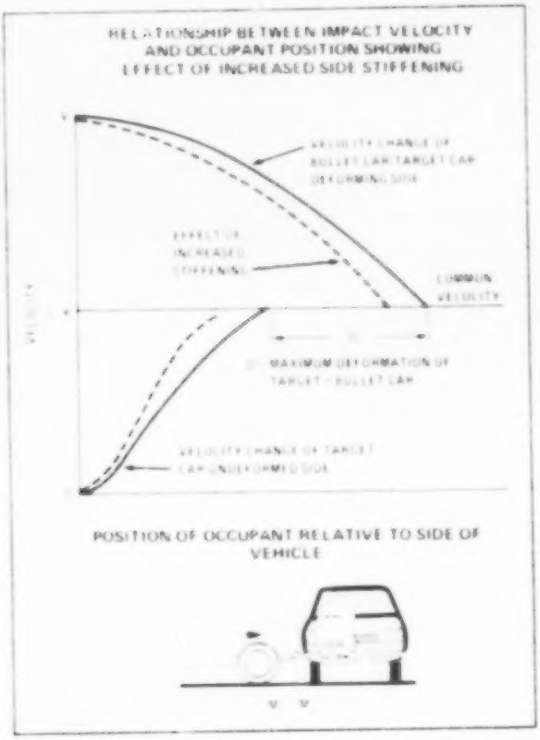

FIGURE 3

MASS AND AGGRESSIVITY

Both mass and aggressivity are functions of vehicle size and design, and to investigate the effects of mixing the extremes, a trio of 90° vehicle to vehicle side impacts was carried out using Escorts and Mark IV's. These tests are referred to later in this report, but one of the chief conclusions drawn with respect to these particular vehicles was that under side impact conditions it is safer to be in a Mark IV hit by an Escort than in an Escort hit by a Mark IV. This is due not only to the greater mass of the Mark IV, but also to the strength of its center door pillar and the greater distance between the occupant and the initial impact. Nor is the Mark IV as dangerous a bullet car as might be expected. Its large flat front proved to be an effective load spreader, and it produced less penetration when impacting an Escort than was produced by another Escort.

As a target car, the large car is safer only if its higher mass is effectively utilized for structural strength. The light car can be made to provide adequate protection, but in impacts between vehicles of differing masses, the secondary impact velocities are higher for the occupants of the lighter car, thus increasing the design problem of providing adequate energy absorption in the space available.

It is difficult to generalize on the effects on side impacts of the high impact bumpers which are legislated in America. While they may improve load spreading in a 90° impact, this benefit may well be cancelled out by the increased structural stiffness which is required to sustain a 5 or 10 mph impact. Their effect in angled impacts will be even more acute, and the opener effect of a reinforced bumper corner very difficult to resist. There is no doubt that some of the design trends which made vehicles safer for their own occupants can make them more dangerous to other road users, and especially to other vehicles not built to the same safety standards.

TEST PROCEDURES

SAE Contoured Mobile Barrier

One of the earliest proposals for a standardized side impact test involved the mobile barrier shown in Figure 4. From any angle, this is a very aggressive piece of equipment, and when used at 45° from the front, the curved-under lower edge, and the almost infinitely stiff corners, combined to take it over the door sill and through the door in a highly effective and unrealistic fashion.

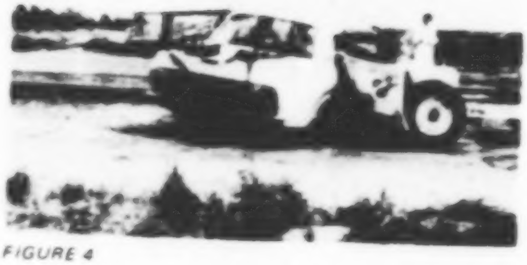

FIGURE 4

Vehicle to Vehicle Angled Impacts

Far more realistic, but still severe, is the vehicle to vehicle impact, and Figure 5 shows the set up for a 45° from the front impact. Figure 6 shows the results of such an impact at 50 km/h on an Escort, while Figure 7 shows the results of a slower speed (33 km/h) impact on a Capri. Figure 8 shows the result of reducing the impact angle to 20° for a 50 km/h impact on a Capri. The effect of reducing either the angle of impact or the speed is to considerably reduce the vehicle damage caused.

Approximately 30% of side impacts are between vehicles whose directions intersect at angles between 0° and 70° from the front. Unfortunately, such data are incomplete, unless the velocities of both vehicles are known in order to determine the true direction of the impact forces. In practice, it is likely that the proportion of actual impacts from the front is more than 30%.

Figure 9 shows some occupant head acceleration data from a 50 km/h 45° vehicle to vehicle impact using standard Mark II Cortinas. As mentioned earlier in this paper, restrained occupants on the far

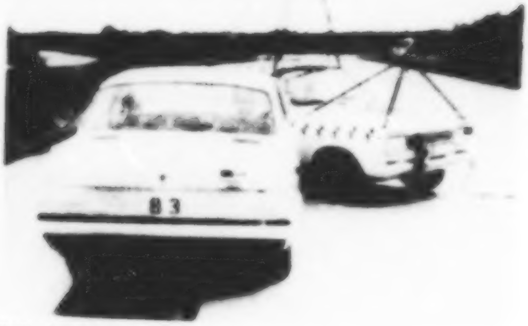

FIGURE 5

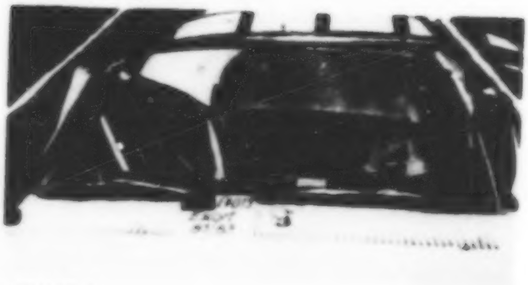

FIGURE 6

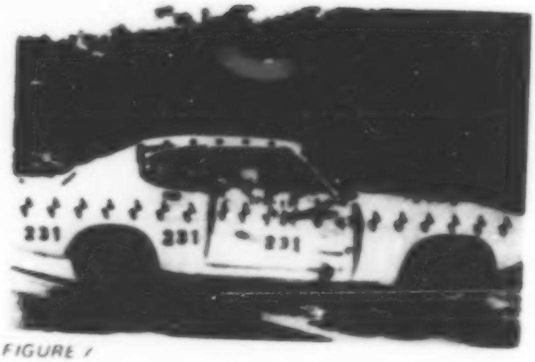

FIGURE 7

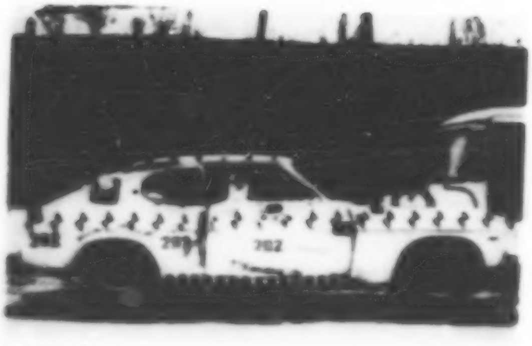

FIGURE 8

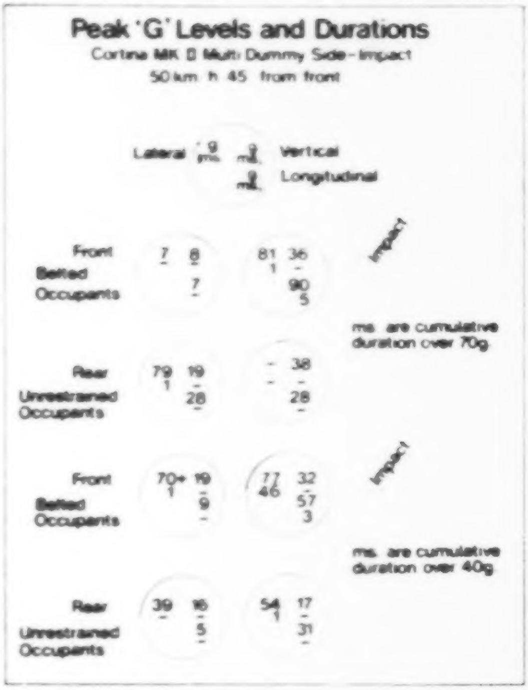
Peak 'G' Levels and Durations
Cortina MK II Multi Dummy Side-Impact
50 km/h 45° from front
Lateral g ms.
g ms. Vertical
g ms. Longitudinal
Front Belted Occupants
7 – 8 – 7 –
81 1 36 – 90 5
Impact
ms. are cumulative duration over 70g
Rear Unrestrained Occupants
79 1 19 – 28 –
– – 38 – 28 –
Front Belted Occupants
70+ 1 19 – 9 –
77 46 32 – 57 3
Impact
ms. are cumulative duration over 40g
Rear Unrestrained Occupants
39 – 16 – 5 –
54 1 17 – 31 –

FIGURE 9

side from impact are relatively safe, which is demonstrated by the lower levels of acceleration.

Vehicle to Vehicle 90° Impacts

The 90° impact has a number of advantages from the analytical point of view, especially in the reduction of rotational effects. It is also a representative case in that about half of all side impacts occur at around this angle. With current vehicles, however, the precise angle is less critical than the precise point of impact. In the worst case, the front sidemembers of a small car may fit neatly between the front and center pillars of some larger or two-door vehicles.

The Escort/Mark IV tests have been referred to earlier, and included Escort into Escort, Escort into Mark IV, and Mark IV into Escort. Figures 10 and 11 illustrate the results of these latter two tests. All the tests were 90° side impacts at 50 km/h. The evidence of the dummy head accelerometers indicated that the impact side front occupant was unlikely to survive in the Escort, but would do so in the Mark IV.

Static Crush

At the same time as these vehicle to vehicle impacts were being carried out, investigations were made into the use of a static crush rig of the type shown in Figure 12. This type of rig has many advantages over other forms of dynamic and vehicle to vehicle tests in that it is inherently more controllable, more repeatable and easier to perform. The main criticism is that it does not directly represent actual crash conditions. Our work showed, however, that the results of this test correlated well with both vehicle to vehicle crash tests and real world accidents. At the same time, they yielded valuable information on the sequence and nature of door and pillar distortion and failures of hinges and locks.

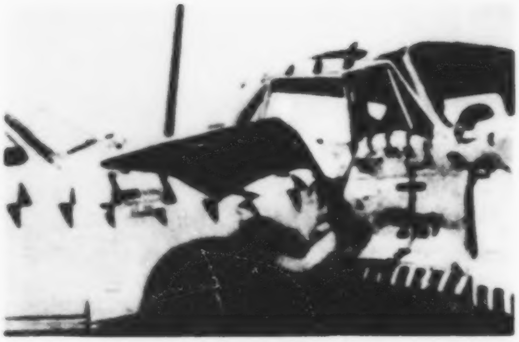

FIGURE 10

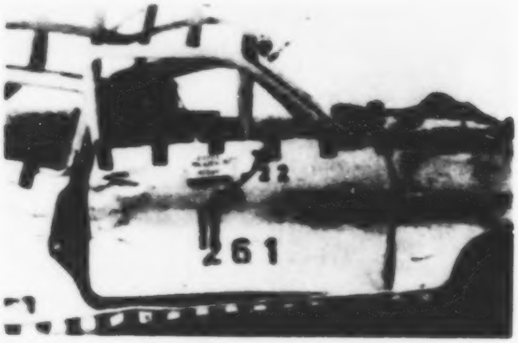

FIGURE 11

In effect, it is not a simulation of a fixed pole impact, but rather of an impact from the corner of a very stiff and aggressive vehicle. While there is no complete substitute for vehicle to vehicle impacts, the static crush test is a valuable development tool which is not subject to the wide range of results scatter found in vehicle to vehicle tests.

Flat Faced Mobile Barrier

Probably because of criticism of the contoured SAE barrier, several later proposals have favored flat faced barriers. An early proposal for testing fuel tank

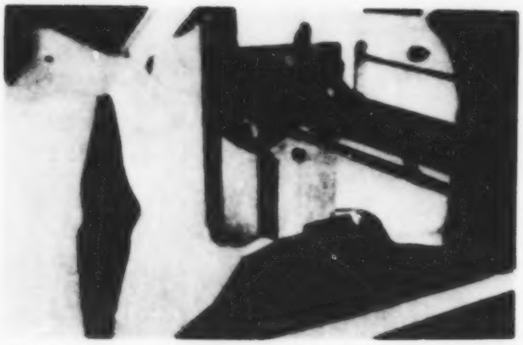

FIGURE 12

integrity in a side impact at 25 km/h is shown in Figure 13. In practice, this is by no means a severe test. A more recent proposal is for the even larger flat face required by FMVSS 208. Figure 14 shows this barrier. It is hard to see what this test represents, as the percentage of injuries caused by vehicles sliding bodily sideways to impact a flat rigid structure at exactly 90° must be extremely small. It has to be considered, therefore, as purely an attempt to assess the protection given to the occupant against secondary impact with the inside of the car.

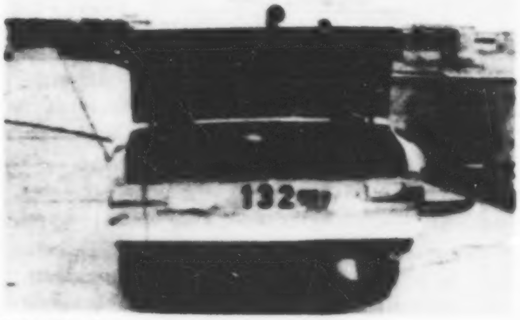

FIGURE 13

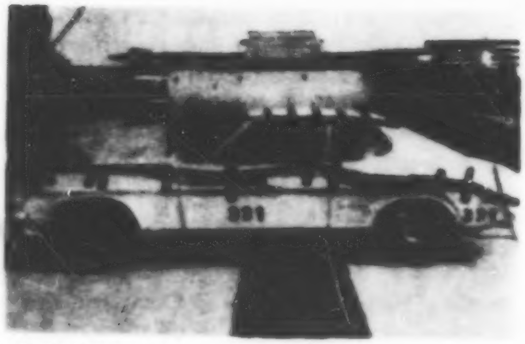

FIGURE 14

The face of the barrier is so large that the vehicle side strength is not at all critical. The occupants' heads on the impact side are likely to strike the side pillars or even the face of the barrier. The critical aspects are therefore the thickness of the door, the effectiveness of any interior padding and the positioning of side pillars relative to the occupants. This latter effect is quite arbitrary as a position which is correct for 90° impact could be equally wrong for an angle of 80° or 100°.

Pole Impact

This test basically represents an impact in which the vehicle slides sideways into a fixed pole, although similar results can be obtained using a stationary vehicle, and a pole mounted on a mobile barrier, as in Figure 15. This type of test has featured in several proposals associated with experimental safety vehicles and undoubtedly much of the reason for this emphasis is the extreme difficulty of protecting an occupant immediately next to the impact, and in the path of the intrusion.

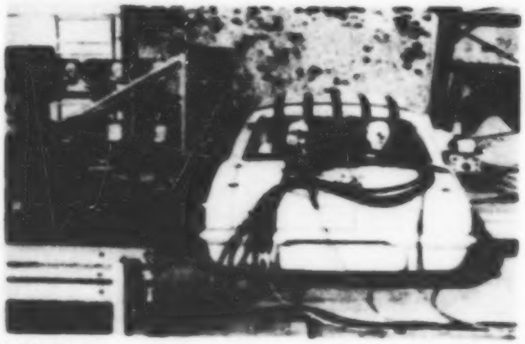

FIGURE 15

However, its frequency of occurrence as a source of serious and fatal injuries is low. Only 20% of side impacts involve fixed objects, and clearly not all of these are pole shaped. Furthermore, because the number of these accidents is small, there is virtually no information on speeds of impact, on which to base a realistic test.

The pole impact can be the hardest of all tests in which to provide protection for the occupant next to the point of impact. In view of its severity and relatively low incidence, a better way of tackling it is through improved design and siting of the roadside furniture involved.

CONCLUSIONS

The work discussed in this paper forms only a small part of the total effort put into safety by Ford of Britain. It was selected to re-emphasize the problems associated with improved occupant protection in side impacts.

The most fortunate aspect of these problems is that at least the most severe cases are also the least frequent. While our work shows that significant improvements can be made with appropriate reinforcement and interior padding, it is also apparent that we must avoid any tendency to isolate the various types of accidents. About half the side impact accidents are also frontal impacts for another car, and the damage and injury caused is dependent on the design of both vehicles. The introduction of stronger and more aggressive front ends for frontal impacts is largely detrimental to side impact performance.

To provide protection in side impacts, the relative merits of increased side strength, and increased interior padding, depend upon the size and weight of the car. Our results suggest that side strength is more critical for the large car, while interior padding is critical for the small car. The real problem for the small car is not strength or weight, but space. Whatever the design, space is required to cushion the violent velocity changes produced by crash conditions. To keep this space to a minimum, we need more real world accident data from which to determine the speeds at which protection should be given. We must also avoid the temptation to be sidetracked by severe and impressive forms of testing, into directing effort into unrewarding areas.

REFERENCES

1. "The Frequency and Severity of Injuries to the Occupants of Cars subjected to Different Types of Impact in Accidents. A Pilot Investigation of Road Accidents in the Winchester Area" G. Grime - University College, London, report.

2. "Protection of Car Occupants against Side Impacts" - R.D. Lister and I.D. Neilson, Road Research Laboratory - 13th Stapp Conference.

3. "Causes and Effects of Road Accidents" University of Birmingham Department of Transportation and Environmental Planning.

THE SWEDISH TECHNICAL PRESENTATION

SECTION 2 PART 3

GENERAL REMARKS

MR. GUSTAV EKBERG, *Chief*

Vehicle Division
Swedish Road Safety Office

Mr. Secretary

Ladies and Gentlemen,

As I mentioned yesterday Sweden has decided to start a research project, "Steerability during emergency breaking," that we believe will be a valuable contribution to the work on safer vehicles. The reasons for our choice of research object are several but I would like to mention two of them.

Firstly, the climate conditions during Autumn, Winter and Spring are very variable in our country with frequent changes between dry road surfaces with good friction and snow and ice with slippery road surface. Our accident investigations indicate that a large portion of road accidents can be related to skidding caused by inadequate or careless use of the vehicle's brakes. We therefore have reason to believe that some accidents could be avoided if vehicles are equipped with brake systems that would prevent locking of the wheels and thus make it possible to maintain the steerability of the vehicle during braking.

Secondly, we are of the opinion that the present specifications for ESV as far as braking is concerned should be complemented with performance standards on the steerability of vehicles under emergency braking and requirements for testing. It is our intention to propose such standards and requirements on the basis of the research work just started.

The costs of the project are estimated to 2.6 million Swedish crowns, equal to about 520,000 U.S. $. They will be equally borne by the government through the Swedish Board for Technical Development and the Saab-Scania and Volvo Companies.

Mr. Sten Rundkvist who has been appointed project leader, will now give a technical presentation of the project followed by a presentation by the Volvo Company on their Experimental Safety Vehicle, called VESC. Mr. Mellde, director of engineering, and Mr. Aasberg, head of analysis section, will now inform us of the vehicle.

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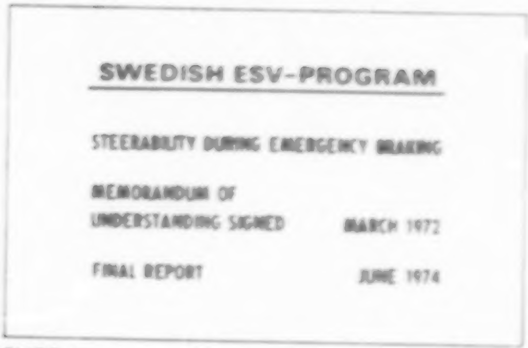
STEERABILITY DURING EMERGENCY BRAKING

MR. STEN RUNDKVIST, *Project Leader*

ESV Project

Mr. Chairman, Ladies and Gentlemen,

The Swedish ESV program is an investigation of steerability during emergency braking. The program is still in the planning phase resulting from the fact that the memorandum of understanding between the Department of Transportation of the United States of America and the Government of Sweden was signed as late as in March this year (slide 1). The final report on the project will be issued in June 1974.



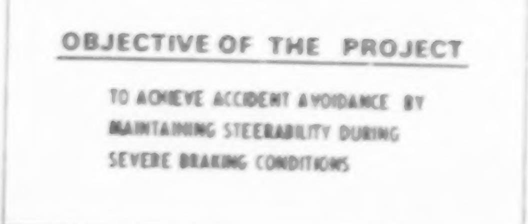
SWEDISH ESV-PROGRAM

STEERABILITY DURING EMERGENCY BRAKING

MEMORANDUM OF UNDERSTANDING SIGNED	MARCH 1972
FINAL REPORT	JUNE 1974

SLIDE 1

In Sweden a large proportion of car accidents are caused by skidding. Due to this fact the objective of our program (slide 2) is to suggest performance standards in order to achieve accident avoidance by maintaining steering capability during severe braking conditions.

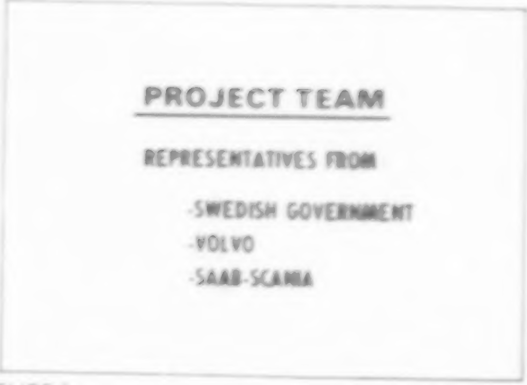


OBJECTIVE OF THE PROJECT

TO ACHIEVE ACCIDENT AVOIDANCE BY
MAINTAINING STEERABILITY DURING
SEVERE BRAKING CONDITIONS

SLIDE 2

In order to realize the program a project team has been established (slide 3) with representatives from the Swedish Government, VOLVO and SAAB-SCANIA in each of the four different tasks in which the program has been divided. One of the delegates in each group has the main responsibility for the quality of work within the available time and cost limits. The project team is backed up with consultants to get as much knowledge as possible into the program.



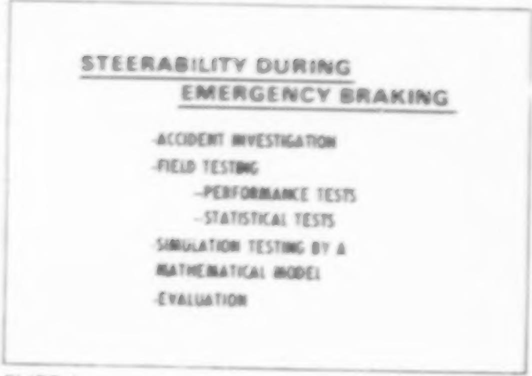
PROJECT TEAM

REPRESENTATIVES FROM

- SWEDISH GOVERNMENT
- VOLVO
- SAAB-SCANIA

SLIDE 3

The four different tasks are (slide 4):



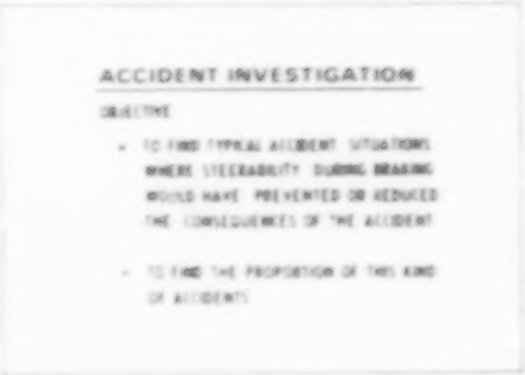
STEERABILITY DURING
EMERGENCY BRAKING

- ACCIDENT INVESTIGATION
- FIELD TESTING
  - PERFORMANCE TESTS
  - STATISTICAL TESTS
- SIMULATION TESTING BY A MATHEMATICAL MODEL
- EVALUATION

SLIDE 4

- Accident investigation
- Field testing, where we intend to have performance testing and statistical testing
- Simulation testing by a mathematical model
- Evaluation

The objective of the accident investigation (slide 5) is to find the most typical accident situations where steerability during braking would have prevented or diminished the consequences of the accident and the proportion of this kind of accidents.



ACCIDENT INVESTIGATION

OBJECTIVE

- TO FIND TYPICAL ACCIDENT SITUATIONS WHERE STEERABILITY DURING BRAKING WOULD HAVE PREVENTED OR REDUCED THE CONSEQUENCES OF THE ACCIDENT
- TO FIND THE PROPORTION OF THIS KIND OF ACCIDENTS

SLIDE 5

The investigation is divided in:

- Study of police reports
- Interviews
- Literature studies

All police reports from car accidents during one year (in a certain district) are studied and all skid accidents are specially categorized in order to find the most frequent situations and, hopefully, also if steering capability would have been of help.

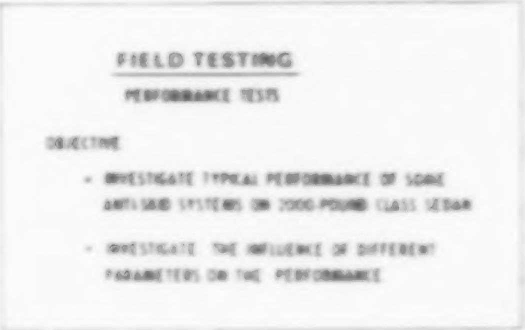
With the interviews we intend to broaden the investigation to critical situations not always leading to an accident.

From the literature study we intend to find the correlation with other countries' experience.

We intend to use the most typical accident situations as a base for the field testing to find out how the anti-skid system can improve the chances to avoid an accident.

The field testing is, as already mentioned, divided into two categories. The first is the performance tests (slide 6), where three, hopefully four, different typical European 2000 pound class sedans, equipped with anti-skid devices on all four wheels, will be tested to investigate the relationship between braking and steering capability (relationship between deceleration and lateral acceleration).

This will be done under different conditions to find the influence of specific parameters for example:



FIELD TESTING

PERFORMANCE TESTS

OBJECTIVE

- INVESTIGATE TYPICAL PERFORMANCE OF SOME ANTI-SKID SYSTEMS ON 2000-POUND CLASS SEDAN
- INVESTIGATE THE INFLUENCE OF DIFFERENT PARAMETERS ON THE PERFORMANCE

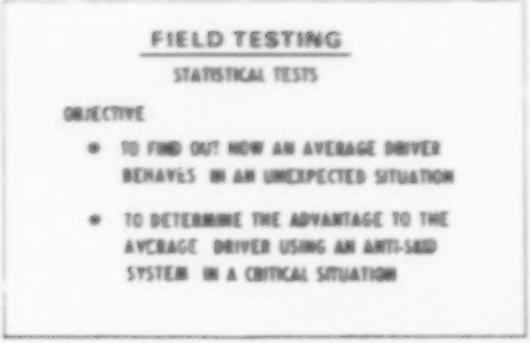
SLIDE 6

- velocity
- friction coefficient (concrete, ice, skid pad)
- vehicle type (rear- and front-wheel drive)
- load condition (normal and maximum)

The measuring device will be a platform stabilized in roll and yaw and measuring longitudinal deceleration, lateral acceleration and yaw velocity. These measured values are tape-recorded and stored in a computer memory for future data processing.

Exactly which test procedure we are going to use is not yet finally decided, since it will be dependent on the accident investigation. The procedure, however, must be reproducible and well defined to make it possible to compare the results with the mathematical simulation.

The second group of field testing is the statistical tests (slide 7), where the objective is to find out how an average driver behaves in an unexpected situation, and further to determine the advantage to the average driver using an anti-skid system in a critical situation.



FIELD TESTING

STATISTICAL TESTS

OBJECTIVE

- TO FIND OUT HOW AN AVERAGE DRIVER BEHAVES IN AN UNEXPECTED SITUATION
- TO DETERMINE THE ADVANTAGE TO THE AVERAGE DRIVER USING AN ANTI-SKID SYSTEM IN A CRITICAL SITUATION

SLIDE 7

We intend to investigate this by means of a special track, simulating the most frequent skidding accident situation, where an obstacle suddenly will appear. A number of statistically selected people are going to use the track to get familiarity with the car, and then suddenly be faced with the obstacle. The registration facilities will be a minimum so as not to confuse the driver, and the main interest is the final position and heading of the car.

The simulation testing by a mathematical model has as objective (slide 8) to complement the field tests and make a systematical investigation of typical anti-skid parameters.

SIMULATION TESTING BY A MATHEMATICAL MODEL

OBJECTIVE

- TO COMPLEMENT THE FIELD TESTS
- TO PERFORM A SYSTEMATICAL INVESTIGATION OF THE INFLUENCE OF TYPICAL ANTI-SKID PARAMETERS

SLIDE 8

For the simulation a hybrid system will be used and it consists of an analog computer with [illegible] integrators and a digital computer with a core memory of 16,000 words, each 16 bits.

The vehicle model is planned to be simulated with 14 degrees of freedom. The functions describing the forces between tire and surface are going to be stored in the digital computer while the vehicle dynamics principally are dealt with in the analog computer.

When the mathematical model is verified through comparison with results from the practical field tests, the performance testing will be simulated where practical tests are difficult to accomplish. This is especially relevant to the systematical investigation of the influence of different anti-skid parameters.

As the statistical tests are very time- and cost-consuming, driver behavior registered during the field tests will be of great help to simulate new accident situations.

When the results from the different activities described are available, the most difficult task remains, namely to evaluate the results (slide 9) and to prove the benefits of an anti-skid system which enables steerability during severe braking. If there are benefits, then performance standards will be suggested and test procedures will be recommended.

EVALUATION

OBJECTIVE

- TO PROVE THE SAFETY BENEFITS OF ANTI-SKID SYSTEMS
- TO SUGGEST PERFORMANCE STANDARDS
- TO RECOMMEND TEST PROCEDURES

SLIDE 9

This is a very condensed presentation of the Swedish ESV program. As already stated, we are still in the planning phase. Cooperation has been discussed with the United Kingdom and France and we are open for any suggestions. We have the usual difficulties in squeezing the program into the frame of budget and schedule, but nevertheless we are convinced that we will carry out the program successfully.

Thank you.

VOLVO ENGINEERING

MR. ROLF MELLDE, *Director of Engineering*

Passenger Car Division

Mr. Secretary,

Ladies and Gentlemen,

It is a pleasure for us and the Volvo Corporation to be able to attend this meeting and to present for you our Experimental Safety Car.

As you may know, this car is not a formal contribution to the official ESV program. However, our objectives [illegible] traffic safety are the same and the requirements for this car are similar in many respects to those set for the ESV.

As car manufacturers it is our task to produce and sell vehicles to the public in competition with others, with all that our products [illegible] at the time, but also in the future. Thus our cars must provide Vehicle Safety, Environmental Protection as well as what I want to call Overall Economy. This means that even if the safety and the environmental protection requirements that must be built into the vehicle are high, the car must be suitable for mass production to really improve traffic safety. The aspect of an Experimental Safety Vehicle has been an important consideration for our Experimental Safety Car, because we are of the opinion that many of the ESV requirements will become standards for production vehicles in the coming years, perhaps somewhat modified in promulgation but of course in design philosophy. Our vehicle safety tradition also calls for a continuous extension of our engineering skills in this field in order to be able to take an active part in future rulemaking procedures with our own developed knowledge. For these reasons, we have also expanded our safety and environmental activities, to be responsive to the pacesetting U.S. market.

SLIDE 1

This constitutes our main philosophy behind the Volvo Experimental Safety Car or VESC, as we call it, and I am now going to give you some details of the development work with this vehicle.

First of all, we have performed a baseline research program with current production vehicles to be able to identify the problems in high velocity accidents. This includes accident investigation and analysis as well as controlled laboratory crashes at impact speeds up to 50 mph against fixed barrier with instrumented dummies, pole impacts, rearward rigid barrier impacts up to 30 mph, car to car side impacts up to 30 mph, angular impacts etc. and I want to show you a short movie from some of these tests.

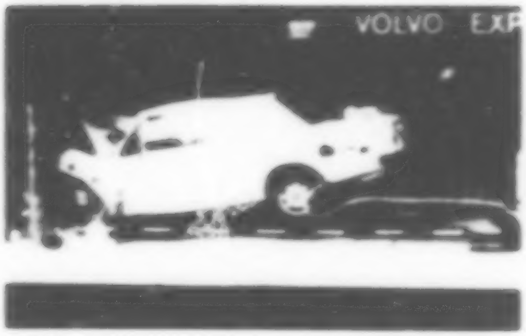
Film

1. Barrier test at 50 mph
2. Pole impact at the same velocity
3. Side impact 30 mph
4. Rear impact into a rigid barrier at 20 mph, 1820 kg

These tests proved the relative crashworthiness of our traditional fundamental design of unitized bodies. The passenger compartment intrusion at side impact, however, must be improved to keep the acceleration of the passengers within reasonable limits. Also, the steering wheel subsystem needs additional design to allow for displacement of the head of a dummy wearing a safety belt, even if this displacement problem is possibly more pronounced with a dummy than with a driver.

However, our next speaker will explain this kind of analysis after my presentation. I only want to mention another crashworthiness design philosophy which seems important to us. Although the front and rear bumper design requirements of the ESV project may have their merits, our goal remains to transmit the impact forces and absorb the collision energy through a deformation distance of sheet metal. This is because sophisticated high energy absorbing bumper subsystems will in our weight class design lead to such increases in vehicle weight and moment of inertia that we would face difficulties with safety related engine performance requirements and accident avoidance handling characteristics.

For this reason the appearance of our safety car after a 50 mph barrier impact will differ considerably from that of the recently crashed U.S. ESV.



SLIDE 2

The accident avoidance specifications for VESC mean no radical change from our traditional requirements, except that some advanced concepts of antiskid systems such as nonlocking brakes will be studied. In addition, new front wheel suspension and steering system layout are incorporated in VESC for evaluation. Furthermore, there are levelling devices for the rear axle. Level-regulated headlamps are also studied and evaluated within the VESC project. The visibility system specifications give some improvements over the present production car specifications, mainly because of the feasibility studies on "pop-up" head restraints incorporated in VESC. This will increase the rearward unobstructed view under normal driving conditions.

Built into the cars for evaluation are also devices for the proposed emission control requirement in the U.S. for 1974.

The crashworthiness design goals for the VESC have been formulated as system requirements for the following set of impacts or simulated accidents.

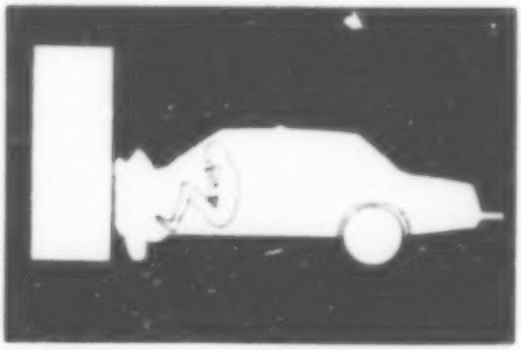
At a frontal impact into a rigid barrier at 10 mph and at a rear end impact into a rigid barrier at 5 mph no damage shall occur to the car. The same is the

SLIDE 3

case at 10 mph with a moving barrier of equal weight to that of the car.

For impacts at higher velocities, design specifications have been formulated as occupant compartment intrusion limitations with the requirements that all four doors shall be operable. Additionally, there are limits for the accelerations of the dummies. The intrusion limits are set at 3 inches, except for side impacts where 4 inches are acceptable. The resultant acceleration limits for the dummies are set at 60 g for the chest and 80 g for the head. It is also required that the measurements of these values are made according to the official ESV specifications.

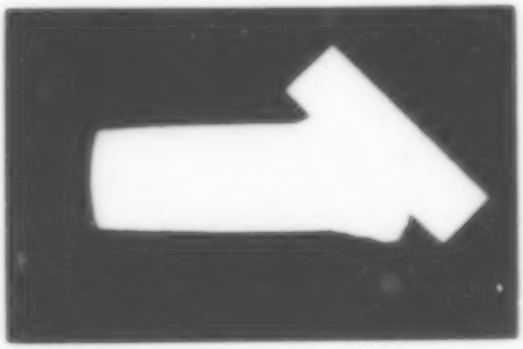
The impact to be performed according to these requirements are head-on impact into a rigid barrier at 50 mph and into a rigid pole at the same velocity.



SLIDE 4

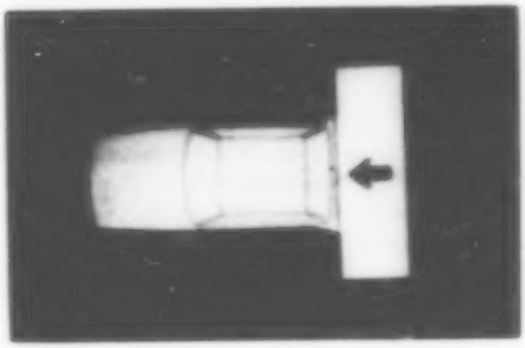
Impact into a 45° rigid barrier at 30 mph is also specified.

The rear end crashworthiness of the vehicle shall be evaluated at a 50 mph straight impact with a rigid



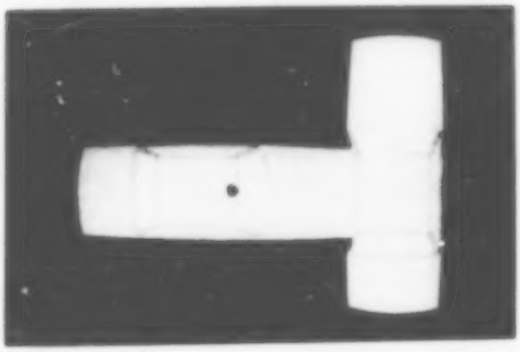
SLIDE 5

moving barrier of a weight equal to that of the vehicle itself.



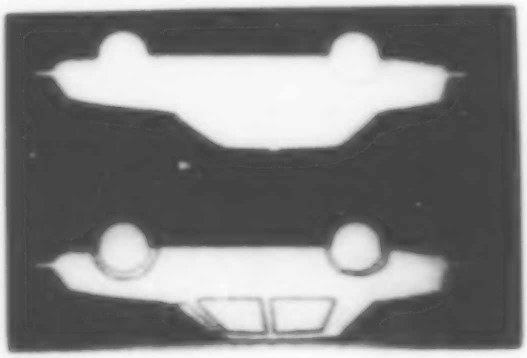
SLIDE 6

The side impact crashworthiness of the vehicle shall be evaluated by two impacts. One is a normal, front to side, vehicle to vehicle impact at 30 mph and the second a vehicle side to rigid pole impact at 15 mph.



SLIDE 7

To evaluate roof strength two tests are scheduled, one in the form of a drop test from a height of 8 feet and the other in the form of a rollover test at 70 mph. The intrusion in the drop test shall not exceed 3 inches and in the rollover test the occupants shall remain within the occupant compartment. This last test may be omitted if a test method which gives repeatable result cannot be developed.

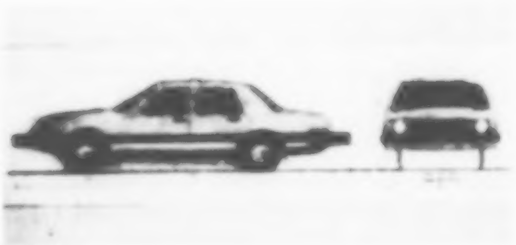


SLIDE 8

I also want to emphasize that these design goals for VESC, which in many respects are similar to the U.S. ESV requirements, may be subject to changes as our evaluation tests proceed.

The development work, according to the goals previously mentioned, has now proceeded so far that today two complete vehicles have been assembled and presented to the public as Volvo's proposals for safety cars.

Both vehicles have the same exterior appearance but the interior safety systems are very different. The total vehicle length is 5,220 mm, the overall height is 1480 mm, the width 1820, the wheelbase is 2,700, treadwidth in the front is 1465, and in the rear it is 1438 mm. The curb weight today is 1450 kg or approximately 3200 lb.



SLIDE 9

The frontal downward view angle is 8.5° and the upward forward view angle is 23.5°. The latter view angle is slightly obstructed by a normal rearview inside mirror. This mirror gives a downward rearview angle of 5.5° and an upward rearview angle of 1.5°. There is a rearward horizontal field angle of 24°

through the [illegible] in the car, which has airbag restraint systems for the protection of the occupants in the frontal and in the rear end impact modes.

In our second vehicle, an advanced design of a 3-point belt system is the main restraint system for the front seat occupants and the feasibility is studied of extensive padding as forward impact restraint system for the rear passengers.

SLIDE 10

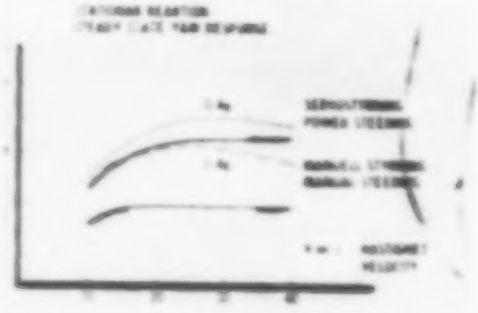
Both vehicles have the fuel tank located over the rear axle. The fuel tanks have a capacity of 80 liters, including 10 liters as fuel expansion chamber.

Furthermore, both vehicles have electronically controlled fuel injection engines of our standard size, with a cubic volume which is 2 liters and a stroke length of 80 mm that gives an output power of approximately 81 kW or 110 SAE hp. Automatic transmission is provided in one of our vehicles.

(More detail of the vehicles will be given elsewhere.)

To assess the accident avoidance data for these vehicles in objective terms, a comparison has been made with the requirements formulated in the U.S. ESV contracts. Simulation of the handling characteristics has been performed according to the same requirements. These simulations show that most of the requirements are fulfilled by the vehicles. The steady-state yaw response with power steering falls outside the limits of the ESV requirements, and has been deliberately chosen to obtain a better dynamic steering response. The validation of simulated handling results is scheduled for the near future.

Testing and evaluation of vehicle crashworthiness and occupant protection systems are scheduled for the coming several years, during which a series of ten vehicles or bodies will be assembled and tested. The



SLIDE 11

crashworthiness theories, design solutions and problems of interest will be presented by our next speaker and I want to end my presentation with some concluding remarks.

These are:

I am convinced that the several ESV projects will promote vehicle safety all over the world and that such vehicle qualities will be ever more based on objective measurements. It is also my conviction that the publicity as such, nowadays devoted to traffic safety, will encourage the public to take an active part in the debate regarding these urgent safety matters.

I also want to express my hope that the schedules for legal actions in different countries in this respect will be coordinated as much as possible, both in time and requirements, so that the automotive engineering resources for these and other important development activities may be used effectively. Thus the final price the consumer will have to pay for these vehicle qualities will be accepted by an increased motoring public.

SLIDE 12

Thank you, ladies and gentlemen!

VOLVO SYSTEMS ANALYSIS PRESENTATION

DR. ARNE ASSBERG, *Head*

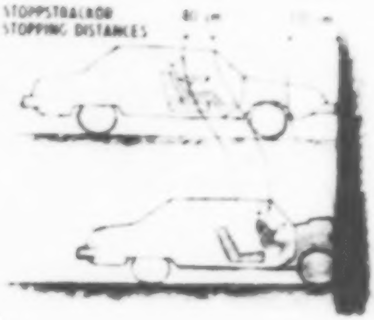
Analysis Section

Mr. Secretary,

Ladies and Gentlemen:

Before this qualified audience, familiar with the problems involved in design of experimental safety cars, such as keeping acceptable the high forces acting on occupants in impacts at 50 mph, I am not going to talk about the importance of having the largest possible deformation distance. Neither do I want to talk about securing the occupants as rapidly as possible at the beginning of the crash. Instead, I would like to talk about the reasoning behind our current choices for some of the subsystem design in the Volvo experimental safety car.

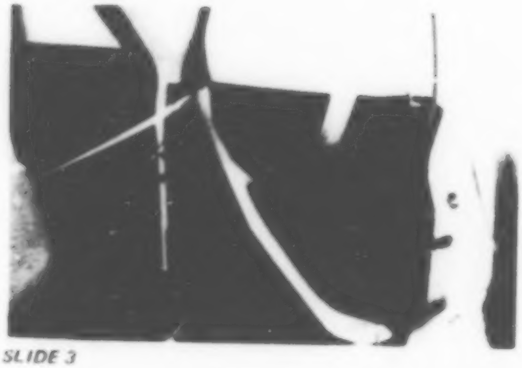
When the deformation distance has been decided upon (slide 1) in view of what will be possible for an interior safety system to handle (slide 2) considering 1) the occupant kinetic energy, 2) amount of momentum and 3) human tolerance to impact forces and internal energy absorption, one will have to select a suitable deceleration pulse for the occupant compartment.



SLIDE 1

For the head-on barrier impact it is our intention to provide occupant protection within ESV acceleration limits for different parts of the body. These accelerations are measured on a test dummy, as mentioned by the preceding speaker. There is an improved 3-point slip joint belt system for the front seat occupants (slide 3), and a combination of a lap belt system and padding for the rear seat occupants (slide 4) in one of our vehicles. Another vehicle has a complete airbag restraint system for the front and back seat occupants effective in both front and rear impacts.

SLIDE 2



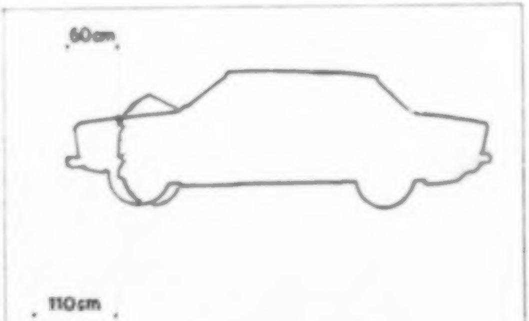
SLIDE 3

These specifications for the interior systems determined the choice of the desired vehicle acceleration pulse as well as the overall deformation distance.

SLIDE 4

We considered this to be two partly contradictory results from: 1) the crash simulations of an occupant restrained by belt systems made by Renneker and 2) the sled test research performed by Stapp and his colleagues about 20 years ago.

Although larger utility could be expected from a high acceleration at the beginning of the impact – as measured by the ratio of the occupant acceleration peak and vehicle deformation distance – the desired ride-down of a rearward facing child seat pressed against the dashboard was decisive argument for specifying a ramp-start acceleration pulse. This pulse levels off at 25 g as design goal for the occupant compartment acceleration in the 50 mph impact. This form of acceleration is designed into the vehicle according to the distances seen in slide 5 utilizing the concept of a diving engine (slide 6). The estimated acceleration rise time of the compartment at 50 mph is 20 ms. This is a rate of onset of 1250 g's which is slightly higher than the roughly 900 g's "permissible" according to the Stapp findings. However, the level to be reached of 25 g is considerably lower than the Stapp sled acceleration level of 40 g. Therefore it seems possible to manage the expected dynamic response or overshoot of the human body in the belt restraint system to survivable values, especially if an advanced belt system with rapid tension device is incorporated to shorten the occupant acceleration rise time, or to increase the apparent system resonance frequency.



SLIDE 5

SLIDE 6

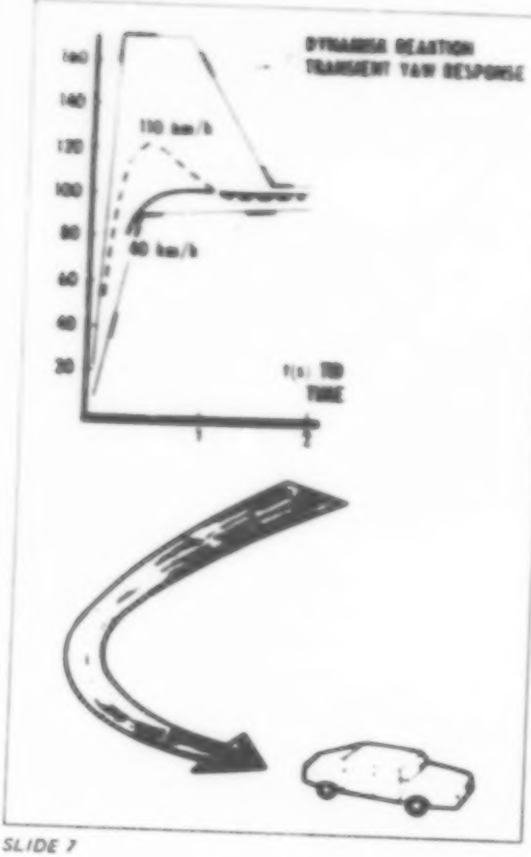
The possibility of levelling off occupant acceleration with a constant force device in the belt has not been judged feasible at this time. This is due to the real world variations in occupant weight, since an increase in weight over the designed optimum force for an average occupant would mean an increase in forward motion of a heavy occupant. Such a consequence is undesired.

In this regard, the concept of a fixed seat position with moveable controls has also been discarded, because the adjustment of the seat, according to the height of the occupant, may give a favorable compensation for the weight of the occupant. A rearward seat adjustment for comfort will shorten the free elongation length of the belt system webbing and the apparent stiffness of the restraint system will increase.

Together with a heavier occupant, this may constitute a lumped parameter mass-spring system, with an automatically adjusted and more constant resonance frequency or rise time. Furthermore, a taller person adjusting his seat backwards will obtain a greater distance for safe displacement inside the vehicle in the event of a crash.

Returning to the acceleration pulse again, a high velocity impact energy absorption bumper system may have merit providing an automatically adjustable levelled square wave acceleration for any impact velocity. This may be favorable with a less acceleration pulse sensitive restraint system such as the air bag system, but the estimated added weight and increase in vehicle moment of inertia may lead to difficulties for transient yaw response as judged from simulations done with 150 kg of added weight front and rear to VESC at a distance of 1.5 meters from the vehicle center of gravity.

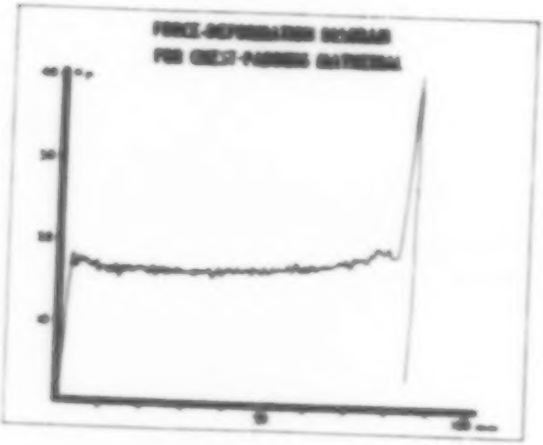
In slide 7 you can see how the transient yaw response curve for the simulated case partly falls outside the ESV specification of acceptable limits.

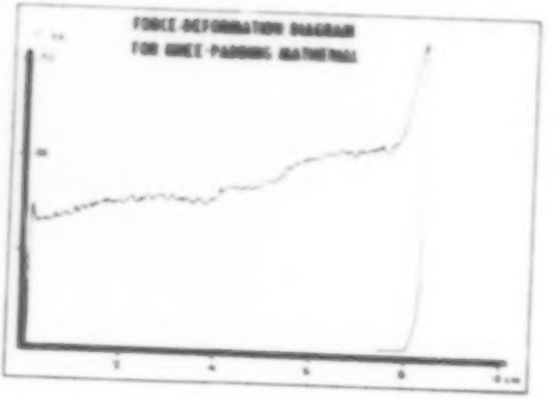


SLIDE 7

Before returning to our philosophy for the belt system, I want to add that the airbag system is built up with knee restraints in the form of padding for surface pressure distribution and energy absorption. The padding also is the transmitting element for femur load forces to a sheet metal backplate which carries these forces to the vehicle.

The static force deformation diagram for our material is seen in slides 8a and 8b. The material is loaded with the flat end of a cylinder of 50 mm diameter and with a total test specimen thickness equal to 10 cm.



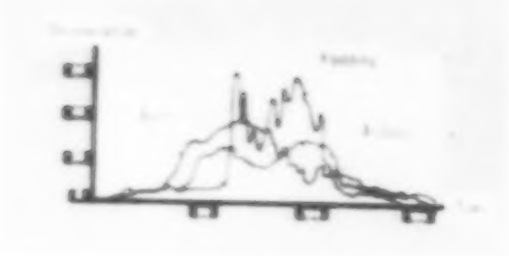


Such material has been used successfully in our advanced engineering with airbag systems at 30 mph barrier impacts on knee impact loads.

The use of bulky padding (slide 9) material as restraint system for the forward moving chest has also been tested. We have performed tests at 30 mph, using the padding mentioned above, as well as a

SLIDE 9

tighter material (slide 10). It has been possible in these tests to keep the acceleration of the chest below 60 g at 30 mph with a constant level of 16 g acceleration of the sled, but the oscillatory spine-mounted accelerometer reading has indicated problems. This is because a nominal design average chest acceleration of roughly 40 g shows superimposed high as well as low frequency oscillations which have taken the properly filtered acceleration peaks up to 60 g for periods approaching the critical limit of 3 ms.



SLIDE 10

To circumvent this problem through improvement of the padding or the dummy, we need further studies to reach a 50 mph impact goal with such a restraint system for rear seated occupants.

Going back to the belt systems, we have identified in our crash tests the problem of the dummy head impacting the steering wheel during the forward-downward motion which is associated with belt system restraints. We therefore decided to explore the idea of a "disappearing" steering wheel (slide 11).

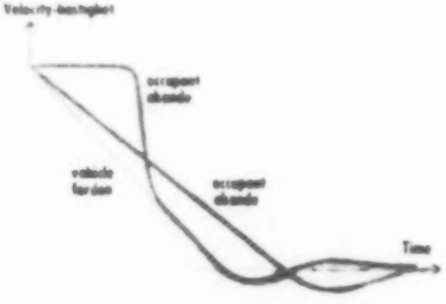
SLIDE 11

The concept is to release the steering wheel from its normal longitudinal position in the car, let it move forward under the influence of inertia and a spring force during impact, when the acceleration level of the car measured near the steering column exceeds that level where the driver can be expected to brace himself with his arms and legs. This level is also chosen with regard to the low velocity impact acceleration level designed for the front bumper subsystem. A disappearing steering wheel at these impact velocities is not desired.

During the collapse of the steering wheel, torque transmission will not be impaired because of splines in the shaft. Thus an accidental disappearance will not impose a loss of steering control.

This kind of system will of course not be suitable with voluntary wearing of seat belts, since an unbelted driver may have very little energy absorption from the steering column in case of an impact. Usually he will have to absorb most of the energy by his own chest as the steering wheel forward motion is stopped at the dashboard after 150 mm of travel. This system is chosen, however, together with our "selfbuckling" 3-point slip-joint belt system and may be lifesaving if the belt system is not rendered useless by the driver.

Our design philosophy for other kinds of impacts has been similar to the one just described, but with regard to the time available today I will only emphasize certain of our conclusions. The side impact protection seems us to be the most difficult task to accomplish if we are to keep the width of the vehicles within conventional limits. The only solution to this problem seems to be to set upper limits to such forces which the front of one vehicle may impress to the side of another vehicle. This would probably ensure that the lateral acceleration of the impacted vehicle is kept low (slide 12).



SLIDE 12

Such restrictions will create conditions under which the lateral acceleration of the door and the occupant on the impact side may be kept at levels shown as tolerable in the relatively rare scientific papers published on these matters and known to us.

Our engineering solutions for attenuation of or resistance to impact forces, and results from our studies on occupant protection systems, will be presented in more details at coming events on these matters as our program continues and evaluation tests are performed. Our program is scheduled to be terminated within approximately three years and by that time I think that generally increased knowledge in this field will be ready for coordinated large scale, real life tests, perhaps during the late seventies.

Thank you, ladies and gentlemen.

THE ITALIAN TECHNICAL PRESENTATION

SECTION 2 PART 4

MR. GIACOMO POCCI, *Chief of the Research Bureau*

Ministry of Transportation

INTRODUCTION

Good morning ladies and gentlemen. It is my pleasure to introduce the Italian technical presentations which will consist of first, Engineer Moscarini, Director of the Experimental Institute for Motor Vehicles (ISAM) who will report on a technical paper titled "Vibrations Influencing Driver's Fatigue." Mr. Moscarini will then be followed by the Alfa Romeo presentations by Dr. Cacciabue on "Passive Restraints" and Dr. Schiappati on "Active Restraints." Finally, Dr. Montabone will introduce the technical presentation by the Fiat S.P.A. Mr. Moscarini.

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ITALY

DR. FLAVIANO MOSCARINI, *Director*

Experimental Institute for Motor Vehicles

ISAM (Istituto Sperimentale Auto e Motori) is a scientific organization involved in applied research.

ISAM is a member of the Italian working group concerned with studies to solve the problem of vehicle safety for the Italian Ministry of Transportation.

Most authorities agree that drivers are responsible for about 90% of all accidents. Recognizing this fact, one understands the vital role played by human factors in accident cases. Human factors, therefore, have to be taken into account in any safety vehicle concept.

ISAM activity is also involved in human engineering. The first item is intended to define new standards for acceptable vehicle driving characteristics. The second subject is concerned with research on driver environment conditions in the car, especially from the viewpoint of effects on the driver's reaction. This subject may be divided in two different parts: first, the design of really psychological seats easily adaptable to a wide range of people; and second, research on vibrations transmitted by the car to the driver. These vibrations cover a wide frequency range from ultrasound to infrasound and their effects have to be accurately investigated. The difficulties in accomplishing this research arise because suitable instruments are not available as noted by authorities such as Bryan, Tempest and Mohr.

We are working in vibration research field in cooperation with the Department of Sport Medicine of the University of Rome, and we hope to have in the near future some interesting results on the effects of vibrations on man. To conduct these investigations, we have almost completed a vibrating platform on which a seat may be mounted and then excited at different vibration frequencies. We are also planning the design of a system able to apply contemporarily different vibratory waves to the platform. In this manner we will also be able to investigate the effects of a random vibration pattern. The platform design allows us to study vibration effects on human vision through the wind-screen, both inclined and curved. It allows us, at last, to study modifications of human eye capability due to effects of vibrations and sounds.

FRONTAL CRASH – INFLUENCE OF THE DECELERATION MODE (AT THE SEAT BELTS ANCHORAGE POINTS) ON SEVERITY INDICES

DR. ANTONIO CACCIABUE *Expert,*
Motor Vehicles Safety Design Office

INTRODUCTION

The purpose of restraining devices for vehicle occupants is that of ensuring, during the crash, their connection to a practically undeformable part of the vehicle in such a way that the deceleration mode of the dummy is as uniform as possible, and its level as low as compatible with the crash conditions and the available "ride down" distance. An ideal occupant restraint system should be able to ensure the above mentioned conditions for all the vital parts of the body, which must be considered as a system with many degrees of freedom, and a certain number of masses interlinked by means of free and relatively weak hinges, through which only comparatively modest forces can be transmitted.

In order to approach as much as possible such an ideal, actual restraining devices are generally made up of a few components, which reciprocally interact. More specifically, a safety belt (the component we intend to examine here) has the job of restraining the central part of the body directly, and only indirectly the extremities, such as head and legs, according to whether there are other, complementary restraining systems. As we have already mentioned, a satisfactory study of the stresses imposed on the body during a frontal crash, especially on those parts not directly restrained by the belt, involve a several degree of freedom approach, taking into account the complex contour conditions. Such simulations, which are now widespread, can give interesting overall indications; but due to the great number of variables involved, do not appear suitable to emphasize efficiently the influence of safety belts characteristics and of the deceleration modes of their anchorages on the dummy's motion.

To this end we believe quite useful a simple scheme limited to the central part of the body, which is assumed to be a concentrated mass, connected to the vehicle by means of a belt with given deformation characteristics. The law of motion of the belt anchorages is also assumed known.

We would again like to stress that such a simplified scheme cannot give reliable results for the whole dummy, even if we consider it quite suitable for the present purpose.

The Severity Indices thus obtained are only indicative values, and serve for comparison between different belt solutions, and deceleration modes.

MATHEMATICAL TREATMENT

From Figure 1 we obtain the scheme used afterwards for the discussion of Figure 2.

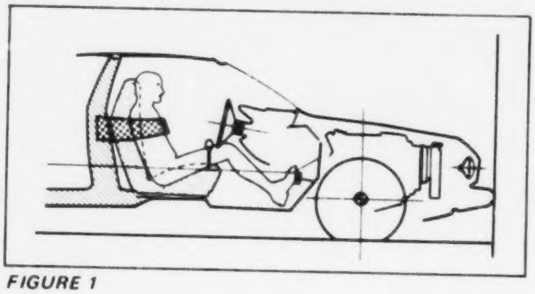


FIGURE 1

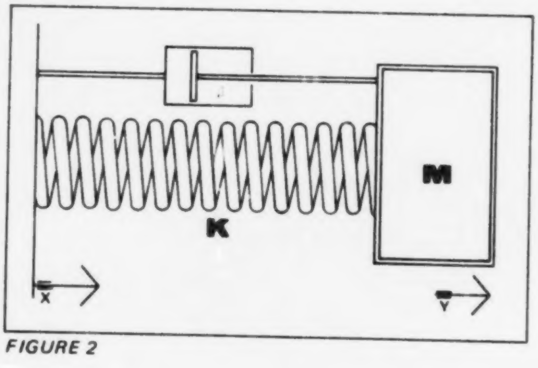


FIGURE 2

We have:

x = total displacement

x = total displacement of the belt anchorage point during the crash.

y = total displacement of the mass restrained by the belt during the crash.

at time $t = 0$, $x = 0$ and $y = 0$.

k = elastic rigidity of the belt.

β = viscous damping coefficient of the belt.

Assuming a displacement law for x, then the motion of y can be studied, for given values of belt elasticity and damping coefficent.

Anchorage displacement law

Figure 3 shows an experimental diagram (obtained from actual crash test results of one of our production cars) for the deceleration of a point on the body, which may be considered a belt anchorage. This diagram shows also the velocity and displacement curves. From this it can be seen that for a 30.95 mph crash the anchorage point displacement is L = 0.65 m.

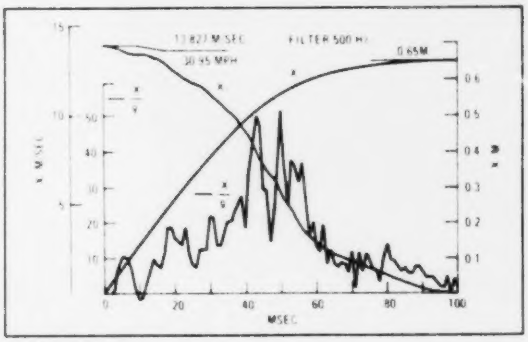


FIGURE 3

Occupant mass and elastic charactersitics of the belt

In the following calculations a mass of 65.7 Kg was considered, assuming that part of the body mass, indirectly restrained by the belt, would be restrained by other complementary systems. The belt is characterized by a constant rigidity k, and by a viscous damping coefficient β. This assumption approximates quite closely to the actual behavior of existing safety belts. Two cases were examined:

- Conventional "elastic" belts, characterized by low damping. The assumptions were:

$$k = 10000 \text{ Kg/m}$$
$$\beta = 0.5\ \beta_{cr} = \sqrt{km} = 258.6\ \frac{\text{Kg. sec.}}{\text{m}}$$

- Critical damping belts.
  To enable us to compare the results of this belt with the one above, it was decided to assume a value for k and for the corresponding damping coefficent $\beta cr = 2\sqrt{km}$, such that the maximum elongation obtained was the same as the one with the "elastic" belt.

Procedure for comparing the two belts.

The comparison was done by studying the law of motion of the mass m for each type of belt, and assuming the following Severity Indices (with respect to the anchorage points and the mass of the dummy) as a comparison yard-stick:

$$\text{SIX} = \int_0^t \left(\frac{|\ddot{x}|}{g}\right)^{2.5} dt$$

$$\text{SIY} = \int_0^t \left(\frac{|\ddot{y}|}{g}\right)^{2.5} dt$$

To evaluate the SIX, the integral was taken over the whole duration of the crash (100 msec.) For SIY, instead, the integral was taken only up to the point where $\ddot{y}$ changes sign.

ANALYSIS OF THE RESULTS OBTAINED

Figures 4 and 5 show the diagrams of decleration, Severity Indices, velocity and displacement of the anchorage points and of the mass m, for both types of belts considered. In the following table we have shown the Severity Indices obtained, and also their ratio.

k Kg/m	β/β_{cr}	Max. Elongation m	SIX	SIY	SIY/SIX
10000	0.5	0.150	186	190	1.022
5500	1	0.150	186	144	0.774

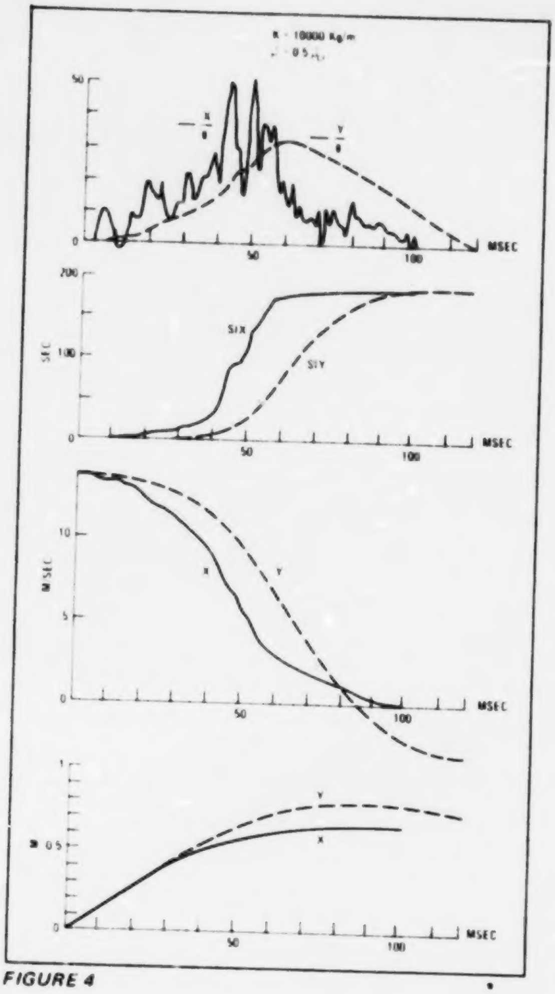


FIGURE 4

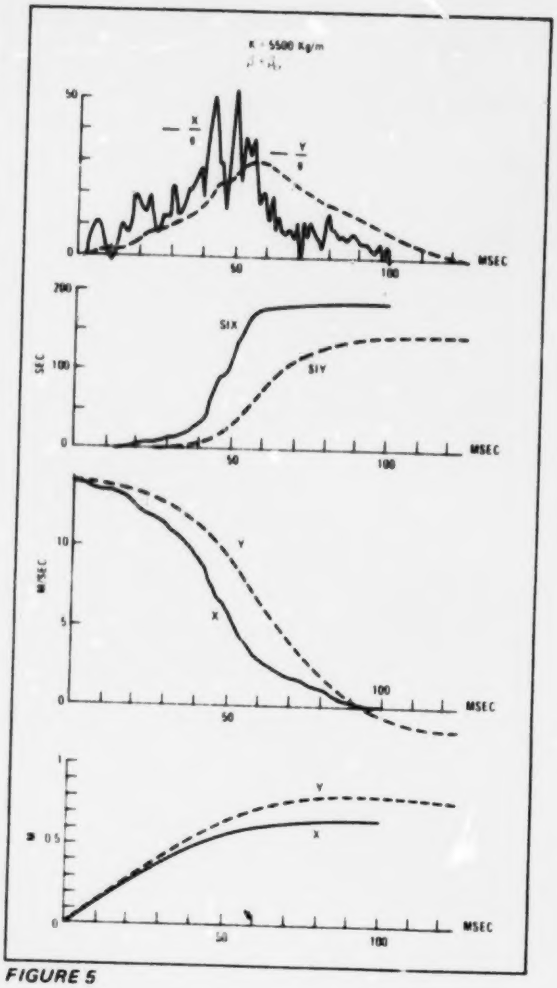


FIGURE 5

We can observe the following points:

- The Severity Index for the mass m obtained with the critical damping belt is lower than the one obtained with the conventional belt.
  The better behavior of the former belt was found also using anchorage deceleration diagrams widely differing from the one used in the above mentioned calculation.
- For both types of belts, it was noted that the Severity Indices calculated for the mass m and for the anchorage points did not vary greatly.

It would be possible to obtain significantly lower values for the Severity Indices using "constant force" belts, which would give a close approximation to the ideal of a rectangular deceleration diagram for the mass m.

In this case we would have:

$$(SIY)_{id} = \frac{u^4}{[\,2(L + \Delta L)\,]^{1.5}\, g^{2.5}} = 59.9$$

where:

u = crash velocity = 13.827 m/sec.

L+ΔL = total mass displacement = 0.65 + 0.15 = 0.8 m.

- The contour of the mass deceleration diagrams, for both belts, is smoother than the corresponding one for the anchorage points.

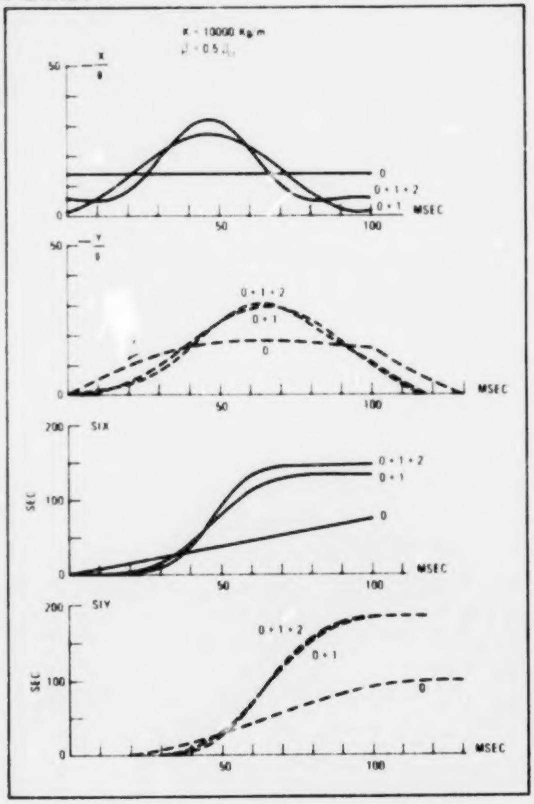
RESEARCH ON THE BELT FILTERING EFFECT

The experimental diagram shown in Figure 3 was developed using Fourier series (with a base of 100 msec.), in order to establish the importance of the belt filtering effect on the Severity Index of the mass m. This development was carried out up to the tenth harmonic. Using both belts under consideration, a series of calculations was performed, with anchorage deceleration diagrams built up starting with the constant component of the development, and successively adding the various harmonics, up to the tenth.

Figures 6 and 7 show the diagrams corresponding to the first 3 deceleration laws.

In the following table, and in the diagram of Figure 8, we have shown the values of SIX, SIY and SIY/SIX for excitation diagrams drawn with the successive addition of harmonics up to the tenth. It can be seen that the filtering effect of both types of belts is such that the contribution of those harmonics higher than the first to the Severity Index is practically nil.

FIGURE 6



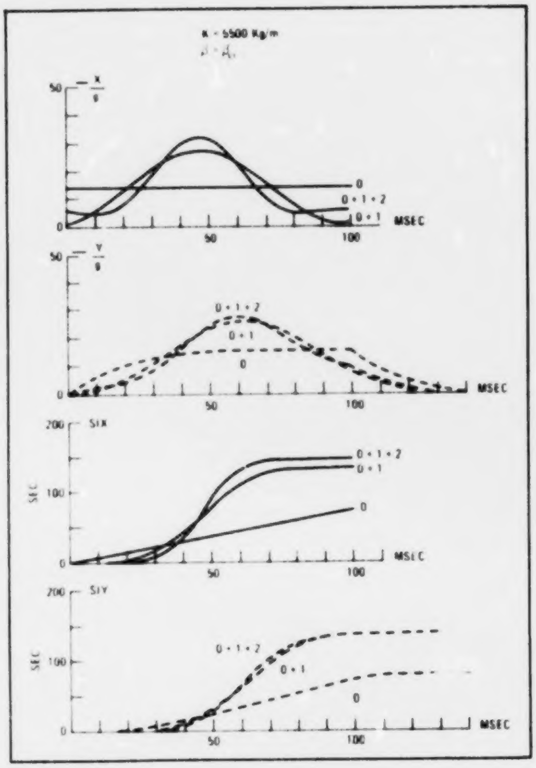


FIGURE 7

Σ Harmonics	SIX	SIY $\beta = 0.5\beta_{cr}$	SIY $\beta = \beta_{cr}$	SIY/SIX $\beta = 0.5\beta_{cr}$	SIY/SIX $\beta = \beta_{cr}$
0	75.	100.	81.	1.33	1.08
0 ÷ 1	134.	186.	140.	1.39	1.04
0 ÷ 2	148.	185.	141.	1.25	0.95
0 ÷ 3	158.	187.	142.	1.18	0.89
0 ÷ 4	159.	187.	142.	1.18	0.89
0 ÷ 5	159.	187.	142.	1.18	0.89
0 ÷ 6	160.	187.	142.	1.17	0.89
0 ÷ 7	160.	187.	142.	1.17	0.89
0 ÷ 8	163.	187.	142.	1.15	0.87
0 ÷ 9	165.	187.	142.	1.13	0.86
0 ÷ 10	166.	187.	142.	1.13	0.86
. . .					
0 ÷ ∞	186.	190.	144.	1.02	0.77

CONCLUSIONS

The traditional, elastic type belts examined gave similar Severity Indices for the mass and for the anchorages. Some improvement could be obtained

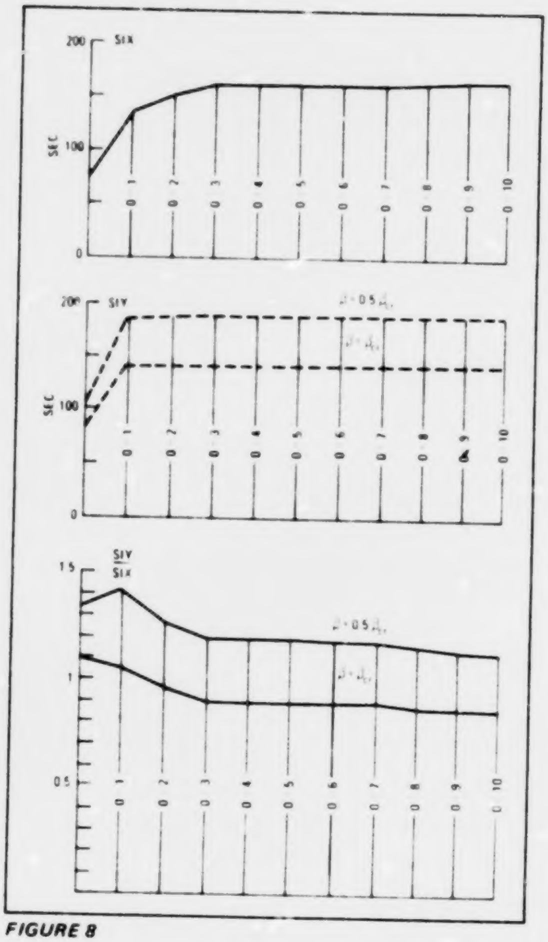


FIGURE 8

with critical damping belts. Much better results could be given by constant force belts.

It must be pointed out, however, that the Severity Indices calculated were relatively low.

The filtering system, consisting of the body mass (assuming attached to the free end of the belt) and of the elastic rigidity of the belt, renders the mass rather unsensitive to the shape of the deceleration diagram attributed to the anchorages. More particularly, only the first harmonic of the Fourier series development of the excitation diagram can make a noticeable difference to the Severity Index of the mass restrained by the belt. This is mainly due to the low frequencies inherent in the mass–belt system, which are (for $\beta = 0$):

K = 10000 Kg/m f = 6.15 Hz
K = 5500 Kg/m f = 4.56 Hz

while the lowest frequency of the exciting system is 10 Hz, for an impact duration of 100 msec.

The experimental deceleration diagrams for the anchorage points may be considered indicative of the stress imposed on the occupants, only if the higher order harmonics (which do not modify the phenomenon) are neglected.

From the results obtained, it seems logical to give rather little importance to the shape of the deceleration diagrams of that part of the body structure which remains practically undeformed, and especially to the belt anchorage points. It is quite sufficient if the deceleration diagram has a "compact" area for the time interval in which vehicle deformation takes place, while even the high "peaks" of decelerations have negligible effect on the occupants Severity Indices. Hence it is better to attribute much more importance to the usable "ride down" distance, considered as the sum of the vehicle deformation and the maximum belt elongation allowed by the size of the interior and its deformation.

We believe that this distance could be usefully increased without revolutionizing the architecture of present-day vehicles, and without substantial cost, weight, size and performance penalties. For example, noticeable advantages could be obtained by adopting short engines, and reducing the rearward movement of the steering wheel, below the limit imposed by the present legislation. Other possibilities to be considered are bumpers which extend as the vehicle speed increases.

For the vehicle energy absorbing structure, having noted that the obtainment of a deceleration law similar to the ideal one is not essential, the purpose of studies and research must become:

- The obtainment of the optimum amount of deformation of the structure with an acceptable deceleration law. This optimum is, obviously, the one which provides the greatest distance for the occupants to decelerate.
- The achievement of the lowest possible weight.

In the light of this, the difficulties of structural studies become less severe: a structure, which has not been optimized for stress and deformation distribution during the impact, will show a weight penalty, but not necessarily worse occupants Severity Indices. It must be remembered, of course, that the abovementioned weight penalty has important effects on cost and road-holding.

ACTIVE SAFETY.
A CONTRIBUTION TO THE STUDY OF THE VEHICLE-DRIVER SYSTEM.
A FIRST APPROACH TO THE DEFINITION OF AN UNDULATION SURFACE FOR ROAD-HOLDING TESTS.

DR. ING. ANGELO SCHIAPPATI
Alfa Romeo Technical Staff

INTRODUCTION

At the Second International ESV Conference in Germany, we talked about Alfa Romeo's opinion on Active Safety. More particularly, we showed the phases which experimental and theoretical research undergo:

- An experimental study of the vehicle-driver system, as knowledge in this field is still insufficent. This was shown, amongst other things, by the doubts and criticism on the American ESV requirements on active safety observed during the Stuttgart conference.
- Interpretation and generalization of the experimental study using sufficiently reliable mathematical models. Actually, it is practically impossible to carry out completely satisfactory tests which will allow a clear understanding of each of the most important dynamic parameters of vehicle motion. This is mainly due to the variation in the behavior of different drivers and, even for the same driver, the variation with respect to time. It is instead possible to estimate, from experimental data, a standard driver behavior, and hence evaluate the influence of those parameters related to vehicle motion, by using an appropriate mathematical model.
- The obtainment of dynamic parameters for the optimization of the vehicle and of the acceptable limits for the variation of real parameters from the optimum configuration.
- A study of objective experimental tests to establish if the vehicle dynamic behavior falls within acceptable limits.

In what follows we show some of the results obtained from research on the driver-vehicle system (points a, b, c) and on experimental tests (point d).

DRIVER-VEHICLE SYSTEM RESEARCH

A series of experiments (which is still continuing today) was carried out on our vehicles, with different drivers and maneuvers. Most of this work was done on the following two maneuvers:

- Entry to and exit from a circular arc bend joining two perpendicular straight lanes.
- Change of trajectory on a straight road, simulating a lane changing maneuver to overtake, or to avoid an obstacle which was noticed rather late by the driver (for instance, a queue of stationary vehicles).

Having established the dynamic characteristics of the vehicle, the experimental results were utilized to define the driver behavior using two parameters, according to the mathematical model we showed at Stuttgart last year. In other words, the driver's reaction time and the parameter for the accuracy of the extrapolation estimate were obtained through a regression analysis performed on a certain number of vehicles and drivers, neglecting evaluations on either particularly good or bad drivers.

Hence, considering the driver's characteristic parameters constant and starting from a configuration typical of one of our production vehicles with good road-holding, a study on the effects of varying a great number of dynamic parameters of the vehicle was carried out. Below we show some of the more interesting results thus obtained, pertaining to the straight road lane-changing manoeuvre. More particularly, we will discuss the influence of some of the parameters chosen from the ones most susceptible to variations, especially considering the structural modifications envisaged to conform to possible future passive safety requirements.

Vehicle characteristics

Case 0 – Base vehicle

total mass of the vehicle (60% of maximum load)	137.5 Kgsec^2/m
sprung mass	120.3 Kgsec^2/m
wheelbase	2.57 m
distance of the vehicle center of gravity from the front axle	1.235 m
distance of the vehicle center of gravity from the rear axle	1.335 m
front track	1.32 m
rear track	1.27 m
height of the center of gravity of the vehicle	0.5 m
distance of the center of gravity of the sprung mass from the roll axis	0.33 m
front roll center height	0.02 m
rear roll center height	0.38 m
front unsprung mass	7.14 Kg sec^2/m
rear unsprung mass	10.20 Kg sec^2/m
height of the center of gravity of the front unsprung mass	0.286 m
height of the center of gravity of the rear unsprung mass	0.286 m
vehicle moment of inertia about the yaw axis	202.4 Kgmsec^2
moment of inertia of the sprung mass about the roll axis	52.05 Kgmsec^2
product of inertia of the sprung mass for yaw and roll axes	25.59 Kgmsec^2
front roll stiffness	2524. Kgm/rad
rear roll stiffness	908. Kgm/rad
front roll damping	365. Kgmsec/rad
rear roll damping	350. Kgmsec/rad
static camber on front and rear wheels	0.
front wheels camber variation per unit roll angle	0.92
rear wheels camber variation per unit roll angle	0.
front roll steering	0.
rear roll steering	0.

Equation for the side force F for the tire:

$$F = \frac{3}{2}\ \mu\ \frac{\alpha}{\alpha_m}\left[1 - \frac{1}{3}\left(\frac{\alpha}{\alpha_m}\right)^2\right]P$$

where:

μ = limiting coefficient of friction = $\mu_o\left(1 - \frac{P}{22_m}\right)$

μ_o = coefficient of friction for $P = 0$ or $P_m = \infty$

α = slip angle.

α_m = slip angle which, for P = constant, gives the max. lateral force.

P = vertical load on the tire.

P_m = vertical load which, for α = constant, gives the max. lateral force.

for the front tires : $\mu = 0.9$ (for static load)
$\alpha_m = 9°$
$P_m = 500$ Kg

for the rear tires : $\mu = 0.9$ (for static load)
$\alpha_m = 9°$
$P_m = 500$ Kg

front axle lateral force variation per unit camber angle	700. Kg/rad
rear axle lateral force variation per unit camber angle	650. Kg/rad

Equation for the rolling resistance R of the vehicle:

$R = P(a + b\,u^2)$ (Kg)

P = vehicle weight (Kg)

$a = 0.01075$

$b = 6.5 \cdot 10^{-6}$ sec^2/m^2

u = vehicle forward speed (m/sec)

max. vehicle cross sectional area	1.7 m^2
aerodynamic resistance coefficent	0.414
front aerodynamic lift coefficent	0.218
rear aerodynamic lift coefficient	0.019

Starting from the above data, the following variations were considered:

Case 1 and 2 – Degree of understeering.

This was varied by changing the value of a_m (preceding page)

This value was reduced by 20% for the front and rear axle successively, following the scheme below:

	a_m	
	front	rear
Case 1 – Understeering increase	10.8	9
Case 2 – Understeering decrease	9.	10.8

Case 3 – Roll steering.

The following factor was introducted for the rear axle, reducing stability:

$$\epsilon = \frac{\text{Rear roll steering angle}}{\text{Roll angle}} = 0.15$$

It must be remembered that front and rear roll oversteering effects are practically identical.

Case 4 – Simultaneous increase in weight and radius of inertia.

weight increase : 20%

rad. of inertia increase : 10%

These increases could be found in vehicles modified to satisfy passive safety requirements.

We point out that the weight increase influences directly the limiting friction coefficient, according to the formulas shown on the preceding page.

Figure 1 compares the steady state behavior of the different solutions mentioned above with the American ESV limits.

Figure 2 shows a similar comparison for transient state, high speed behavior.

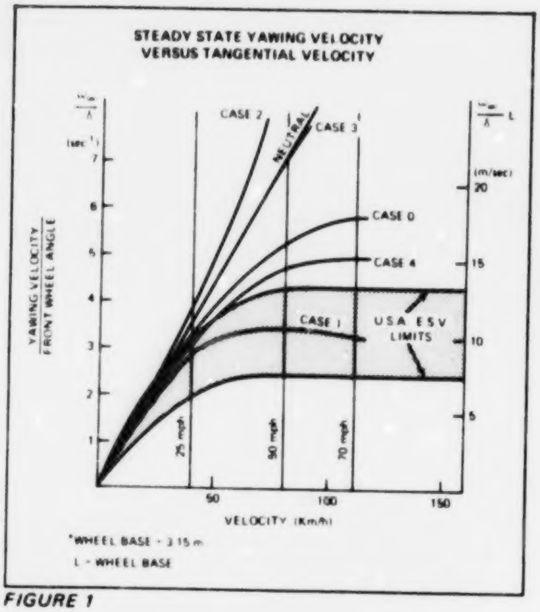


FIGURE 1

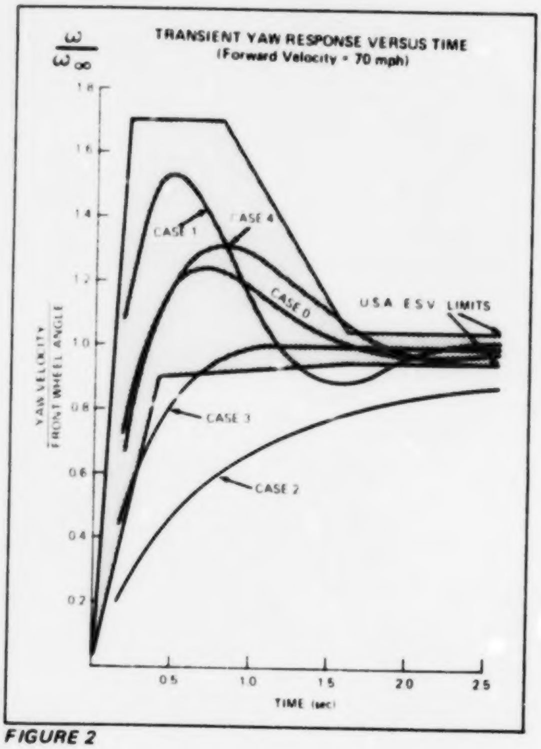


FIGURE 2

It can be seen that only the vehicle with increased understeering (case 1) is within the ESV limits for the steady state test. With the exception of case 2 vehicle (oversteering), all cars are substantially within the ESV limits for transient state yaw.

Change of trajectory on a straight road

The vehicle travels at 70 mph on a straight road having 3 lanes, each 3 m. wide. The initial trajectory of the vehicle is along the centerline of the central lane.

At a point which is halfway of the braking distance required with 0.4 g deceleration from an obstacle using up the central and right hand lanes, the driver decides to change his trajectory, and to follow the centerline of the left hand lane, as shown in Figure 3 and in the following ones.

Figures 3, 4, 5, 6, 7 show the trajectories, the lateral acceleration and front wheels steering angles diagrams for vehicle case 0, 1, 2, 3, 4 respectively.

By examining the above named figures, and the following table, it can be observed that:

- All other factors being equal, a reduction of the degree of understeering (starting from the base vehicle), no matter how it is obtained, reduces the stability of the vehicle. For vehicles case 2 (oversteering) and case 3 (almost neutral), the trajectory diverges.

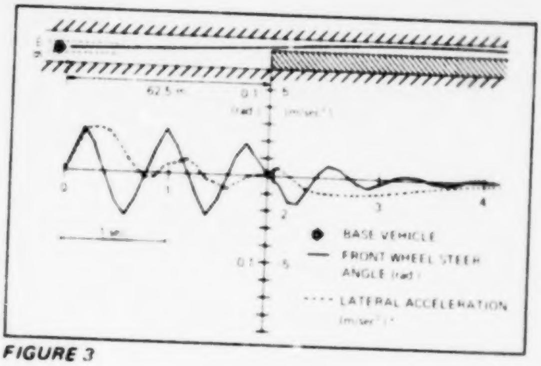


FIGURE 3

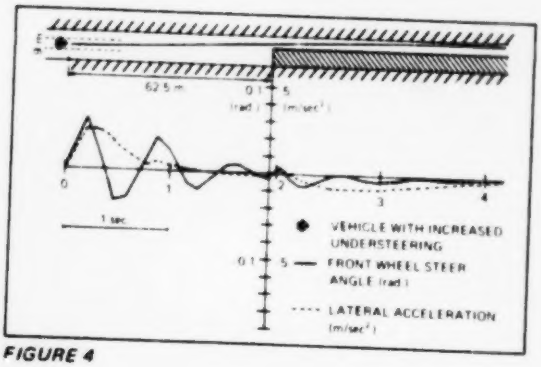


FIGURE 4

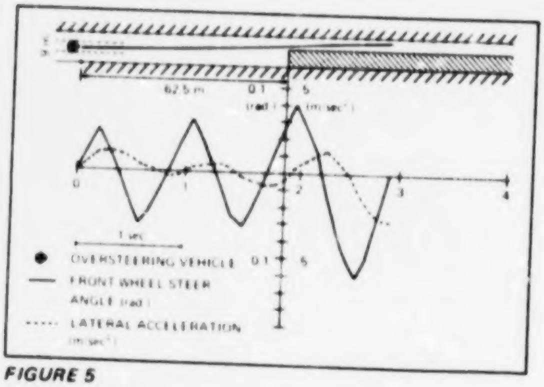


FIGURE 5

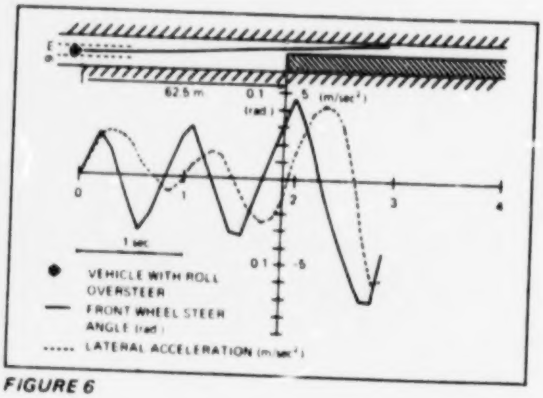


FIGURE 6

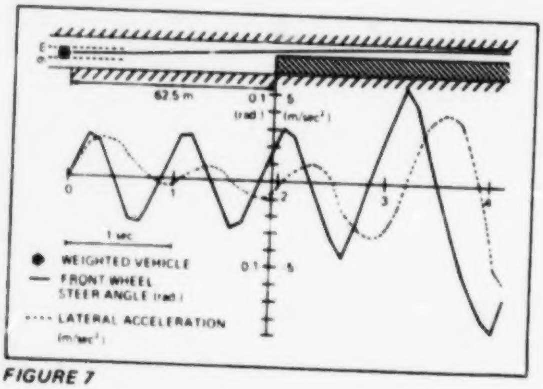


FIGURE 7

On the other hand, an increase in the degree of understeering (case 1) improves vehicle stability, at the cost of decreasing handling quality, as can be observed from the maximum steering angles values measured during the maneuver.

The weighted vehicle too showed an unstable behavior, even if it was more understeering than the base vehicle.

CASE	δ_{max}	Δ°_{max} (18)	Δ°_{max} (28)	Marg.	
0 BASE VEHICLE	0.0506	52.2	81.2	0.39	CONVERGES
1 VEHICLE WITH INCREASED UNDERSTEERING	0.0600	61.9	96.3	0.33	CONVERGES
2 OVERSTEERING VEHICLE	0.1212	125.1	194.5	< 0	DIVERGES*
3 VEHICLE WITH ROLL OVERSTEER	0.1416	146.1	227.0	< 0	DIVERGES*
4 WEIGHTED VEHICLE	0.1691	174.5	271.5	< 0	DIVERGES*

where: δ_{max} = max. front wheels steering angle, in radians.
Δ°_{max} (18) = max. steering wheel rotation angle, for a steering wheel/front wheels ratio = 18.
Δ°_{max} (28) = max. steering wheel rotation angle, for a steering wheel/front wheels ratio = 28.
Marg. = minimum distance of the vehicle from the obstacle (m).

*For all three cases of divergence, the vehicle leaves the road, after complete loss of adhesion.

This was due to the worsening response time of the vehicle, caused by the increased moment of inertia radius with respect to the yaw axis, and by tires which had become undersized as a consequence of the weight increase.

Obviously, this last factor could easily be corrected by fitting wider section tires.

- Taking into consideration only understeering vehicles, it can be observed that there is a vehicle which shows a good behavior, but does not comply with the limits imposed (case 0). The only vehicle which complies with the American ESV proposal (case 1) also shows a good behavior, but is slightly less good in handling.

STUDY OF AN UNDULATED SURFACE FOR ROAD-HOLDING TESTS

A fundamental characteristic of the vehicle, in order to judge its active safety quality, is its behavior on a rough surface. Such behavior involves not only considerations on comfort, but especially on road-holding.

Indeed, even today many busy roads are far from that condition of maintenance, use, and weather protection, which would allow us to disregard the effect of surface roughness on adhesion. We intend to talk about the disturbances caused both by isolated obstacles (such as expansion joins and resurfacing connections) and by casual surface irregularities, which may be represented as a continuous "Power Spectrum," and are characteristic of every type of surface, reaching particular intensity on "pave" and non-asphalted roads.

It is well known that many Research Institutions [A] have undertaken work on the "Power Spectrum" of roads, motorways and landing strips (Figure 8.)

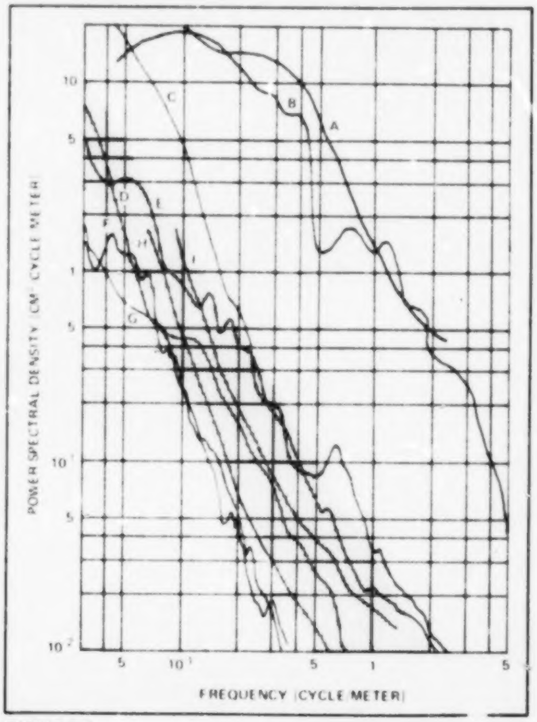


FIGURE 8

Description of the types of roads of Fig. 8

PROFILE	TYPE OF PAVING	SOURCE
A	M.I.R.A. Pave – 1 Section	M.I.R.A. Report 1964/9
B	Endurance test surface	I. Kaneshige S.A.E. Paper 690111
C	Rough French Road	A. Pasquet S.I.A. 10/70
D	Good French Road	A. Pasquet S.I.A. 10/70
E	Medium sized stone slabs	Mitschke Dynamik der Kraftf.
F	Asphalt road, very good	Mitschke Dynamik der Kraftf.
G	Concrete road, reasonable	Mitschke Dynamik der Kraftf.
H	U.S.A. highway, very good	M.I.R.A. Report 1964/9
I	U.S.A. highway, fairly good	M.I.R.A. Report 1964/9

Some authors[B] have reproduced chosen "Power Spectra," actually achieving randomly undulated surfaces.

We believe that, theoretically, such methods of reproduction, or simplified methods (like the one adopted by ourselves [C], can solve very well the problem of simulating profiles of desired statistical and spectral characteristics.

As far as road-holding tests are concerned (and differently from durability tests for mechanical parts), it seems better to use moderately rough surfaces, as they are the most similar to average usage conditions. From an installation viewpoint, this means that the methods [B] and [C] would require a precision incompatible with normal building methods (as the amplitude of the asperities would be about 1/10 that of a durability test pave.)

On the other hand, building precision is required by the practical necessity of condensing in the shortest possible length (a few hundred meters, at the most) the statistical and spectral characteristics of real or chosen standard roads.

All that was said up to now can be summed up in the following conditions, which impose limitations to the practical possibilities for the choice of the type of surface and test:

C1 – Moderately rough surface.

C2 – Admissible errors in the profile amplitudes (of the order of a few millimeters).

C3 – Profile Power Spectrum, representative of real roads, or at least such that the Power Spectral Density decreases as the frequency increases (i.e., as the wave lengths decrease.)

C4 – Power Spectrum extended over a frequency range such that it covers, at the testing speed, at least the frequency interval pertinent to the suspension (0.5 – 20 Hz), or at least the most important frequency band as far as tire/ground contact is concerned (9÷18 Hz.)

C5 – The shortest possible test length, compatible with the need of having at least 3 complete waves of the lowest frequency component.

C6 – Realistic correlation between the profile amplitudes which excite simultaneously the four wheels.

C7 – "Normal" distribution of the exciting amplitudes.

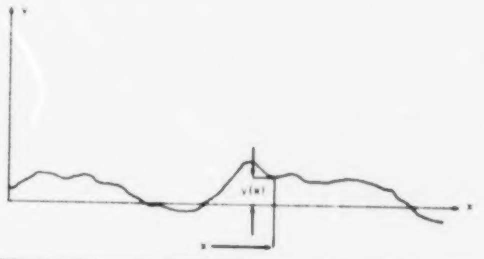
C8 – A suitable test for evaluating an average vehicle behavior during the experiment.

C9 – Moderate test speed, for obvious safety reasons.

The conditions C1-C2-C5-C9 combined, imply the necessity of excluding continuously undulated profiles, such as those generated by sinusoidal, superimposed waves [C].

A profile thus defined may indeed be represented by an equation of the type:

$$y(x) = \sum_{1}^{n} {}_{k} y_k \quad \sin\left(2\pi k \frac{x}{L} + \varphi_k\right)$$



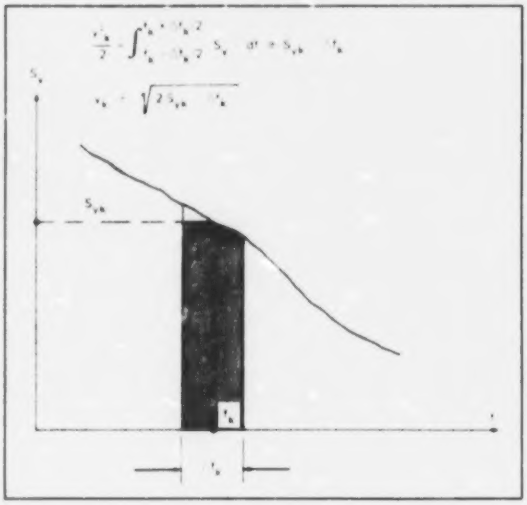
where:

y_k = amplitude of the k^th^ component of the development.

φ_k = phase of k^th^ component of the development.

L = period of the profile function, equal or greater than the total development of the profile.

The phase φ_k is really the casual element of the development. The amplitude y_k has a well-defined value, with respect to the Power Spectral Density S_y of the profile to be reproduced, and to the amplitude of the frequency band Δf_k. The Power Spectrum content of this frequency band is totally debited to the sinusoidal with frequency f_k and amplitude y_k.

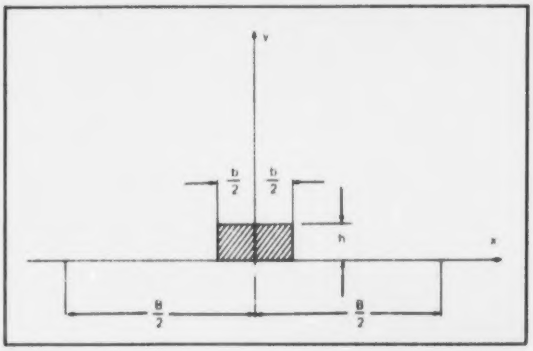


If, for example, in connection with the value f_k = 0.5 (cycles/m) we assume a value $s_{yk} = 2 \times 10^{-2}$ (cm²/cycles/m) and a very large band amplitude, $\Delta f_k = f_k = 1$ (cycles/m), we obtain the following amplitude of the kth component:

$$y_k = \sqrt{4.10^{-2}} = 0.20 \text{ [cm]}$$

This shows the practical impossibility to build, with normal methods and materials, wave lengths equal to or shorter than 2 metres; on the other hand, such length is equivalent to an exciting frequency of 10 Hz, intermediate in the range of frequencies with which we are concerned, even at the considerable test velocity of 20 m/sec (45 mph.)

As a consequence we must resort to asperities which, even though exciting frequencies higher than 10 Hz, are sufficiently high. Such are impulsive type obstacles, which we will represent with a rectangular profile, characterized by a much smaller base than the shortest wave length with which we are concerned.



Considering one of these obstacles, assumed periodic with period = B, it can be described mathematically using a Fourier series:

$$y(x) = \frac{a_0}{2} + \sum_{1}^{\infty} {}_k \left(a_k \cos 2\pi k \frac{x}{B} + b_k \sin 2\pi k \frac{x}{B} \right)$$

$$a_0 = \frac{2}{B} \int_{-B/2}^{B/2} y(x) dx = \frac{2bh}{B}$$

$$a_k = \frac{2}{B} \int_{-B/2}^{B/2} y(x) \cos \left(2\pi k \frac{x}{B} \right) dx = \frac{2h}{\pi k} \sin \left(\frac{\pi k b}{B} \right)$$

$$b_k = \frac{2}{B} \int_{-B/2}^{B/2} y(x) \sin \left(2\pi k \frac{x}{B} \right) dx = 0$$

The amplitude y_k of the kth component of the series development becomes then:

$$y_k = \frac{2h}{\pi k} \left| \sin \frac{\pi k b}{B} \right|$$

For $\pi kb << B$, the above expression becomes:

$$y_k = y_{ko} = \frac{2h}{\pi k} \frac{\pi k b}{B} = \frac{2hb}{B}$$

that is, the amplitude of the components remain constant, independently from k.

Furthermore, the general expression for y_k becomes = 0 for the first time when $\frac{kb}{B} = 1$, i.e. $k^* = \frac{B}{b}$.

We want to find the trend of the amplitudes y_k for $1 < k < k^*$.

$$\frac{dy_k}{dk} = \frac{d}{dk} \left[y_{ko} \frac{B}{b} \frac{1}{\pi k} \sin \frac{\pi k b}{B} \right] =$$

$$= y_{ko}\left(- \frac{B}{b}\ \frac{1}{\pi k^2}\ \sin \frac{\pi k b}{B} + \frac{B}{b \pi k}\ \frac{b}{B} \cos \frac{\pi k b}{B}\right)$$

$$= y_{ko}\left(- \frac{B}{b}\ \frac{1}{\pi k^2}\ \sin \frac{\pi k b}{B} + \frac{1}{k} \cos \frac{\pi k b}{B}\right)$$

To find a maximum or minimum:

$$\frac{dy_k}{dk} = 0 \longrightarrow \operatorname{tg} \frac{\eta k b}{B} = \pi k \ \frac{b}{B}$$

Such condition will never occur for values of $\frac{\pi k b}{B} < \pi$, i.e. for $k < k^*$.

Hence, for $1 < k < k^*$, the value of the y_k components tends to decrease, as the order of the component increases, starting from the initial value ($k = 1$):

$$y_{ko} = \frac{2hb}{B}$$

Hence, we can immediately deduce the possibility of generating a discreet spectrum, containing all the Fourier series development harmonics between the Ist and k^*th order, placing a series of rectangular impulses b.h at a constant interval B which coincides with the fundamental harmonic period ($k = 1$.)

The main disadvantage of such a solution is that the "Power Spectrum" thus obtained, though having a decreasing trend as the frequency increases, it does so following a law which only partially resembles that of real roads.

Anyway, by choosing carefully the parameters b and B, it is possible to have a solution which is acceptable, at least for limited frequency intervals. Because the interval between two successive usable frequencies, in the discreet spectrum, substantially depends on the vehicle speed and on the period B, a moderate speed is required in order to have both a reasonably dense spectrum and, at the same time, moderate obstacle dimensions.

As an example, for a speed of about 11 m/sec (25 mph), it would be appropriate to place the obstacles with an interval $B = 22$ m, to have the exciting components at intervals of 0.5 Hz.

To obtain usable Power Spectrum values at frequencies of the order of 20 Hz, it is necessary that it will not cancel out at less than 30 Hz.

$$k^* \geq \frac{30}{0.5} = 60$$

This means that the obstacle width b must not be greater than $\frac{B}{60}$

$$b \leqslant \frac{B}{60} = 0.366\ [\mathrm{m}] \cong 0.40\ [\mathrm{m}]$$

The obstacle height must be such as to give, in the interval which concerns us (i.e. between 9 and 18 Hz), the desired component amplitude.

If we examine the Power Spectral Densities (P.S.D.) measured from some types of roads all over the world (Figure 8), we can say that, for a frequency of 1.23 cycles/m, corresponding to 13.5 Hz if the vehicle speed is 25 mph, an acceptable value of P.S.D. is 10^{-2} cm^2/cycle/m.

As we have already mentioned, attributing the Power Spectrum content, in the interval from 13.25 to 13.75 Hz, purely to the 13.5 Hz frequency component, we have the following value for the amplitude of such component:

$$y_k = \sqrt{2\, S_{yk}\ \Delta f_k} = 3.10^{-2} \quad [\mathrm{cm}]$$

The obstacle height h, from the considerations above, can be obtained from the following expression (where $k = 27$):

$$h = \frac{\pi k y_k}{2}\ \frac{1}{\sin \frac{\pi k b}{B}} \cong 1.27 \quad [\mathrm{cm}]$$

The suspension excitation method proposed and described above has the advantages of being easy to build, and allowing the use, for the obstacles, of the same material as the one for the smooth parts of the track. The disadvantages are that it considerably stresses the tires, it presents a non "normal" amplitude distribution and a deterministic phasing between the various excitation components: this fault precludes the chance of correlating realistically the excitation on the left and right hand wheels.

To obviate, at least partially, these disadvantages, we propose an alternative method for building the road profile, still utilizing impulsive type obstacles, but smaller and placed in much greater numbers than for the method described up to now. This would allow also a better approximation to real road Spectra. As we have seen, a series of constant interval obstacles causes a certain number of excitation components, the lowest frequency of which is the one fundamental for the obstacles, while the successive frequencies are whole multiples of the first.

Hence it is possible, with a series of obstacles having the fundamental frequency = f_1, to place a second series of obstacles with a frequency between f_1 and $2f_1$, and such that it will not have common multiples with f. This second series of obstacles has a random out-of-phase with respect to the first series. Let the second series frequency be f_2. The same reasoning can be followed for further series of obstacles, say, one having frequency f_3 (and $f_1 < f_3 < f_2$) and without common multiples with either f_1 or f_2; another would have frequency f_4 where $f_1 < f_4 < f_3$, and so on.

If, for example, we assume the frequency f_i to be the geometric mean between the frequencies $f_1 = 1$ and f_i-1, we obtain the following successive frequency series:

1	1.4142	1.1892	1.0905	—
2	2.8284	2.3784	2.1810	—
3	4.2426	3.5676	3.2715	—
4	5.6568	4.7568	4.3620	—
5	7.0710	5.9460	5.4525	—
6	8.4852	7.1352	6.5430	—
7	9.8994	8.3244	7.6335	—
8	11.3136	9.5136	8.7240	—
9	12.7278	10.7028	9.8145	—
10	14.1420	11.8920	10.9050	—
11	—	13.0812	11.9955	—
12	—	—	13.0860	—
—	—	—	—	—
—	—	—	—	—

As we can see, for frequencies higher than a certain value, the successive components generated from the chosen fundamentals mix in randomly, generating a spectrum which shows non-uniform concentrations of components. Then, if such a solution is adopted, the ratio between the highest usable frequency and the lowest of the fundamentals must be restricted; generally such ratio cannot be greater than 3.

Hence it is not possible to excite the suspension with frequencies between 0.5 and 20 Hz, but we will have to limit such interval to between 6 and 18 Hz, where the components most influence tire adhesion.

Below the lowest frequency (6 Hz) there will be no spectrum component, while above 18 Hz there will be very irregular components: fortunately, though, the suspension acts as a filter, in that zone, at least with regards to adhesion, if not to noise. The second method proposed allows to obtain a more regular trend of the "Power Spectrum": indeed, for constant heights of a series of obstacles, the fact of dividing the frequency range into intervals not constant, but proportional to the frequency, results in the association of wider spectrum bands to higher frequency components. Hence, if the components amplitude is constant, we will have a P.S.D. which decreases in an inversely proportional way as the frequency increases.

Having a certain number n of equidistant obstacles series, it will also be possible to give to each series two appropriately different phases to the right and left hand wheels: this will be possible only for the n fundamental frequencies. Figure 9 shows the mean square values, calculated on a base of 200 m and divided by the amplitude of the frequency band to which they refer, of the components for particular examples of both types of paving proposed.

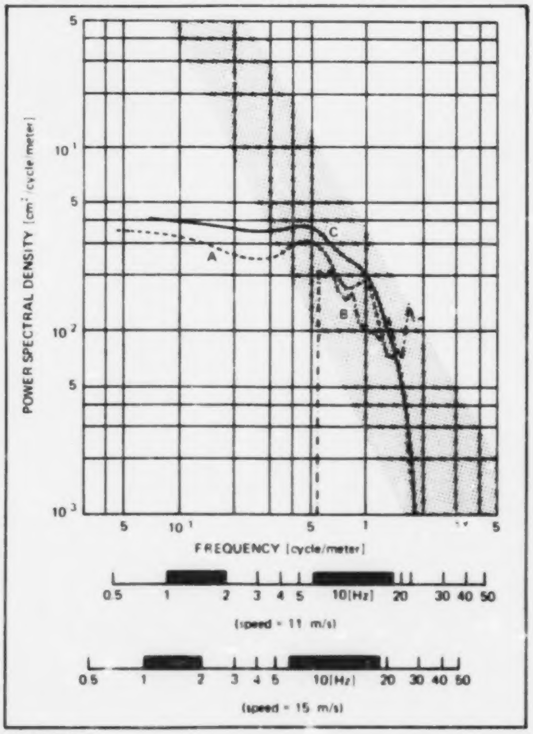


FIGURE 9

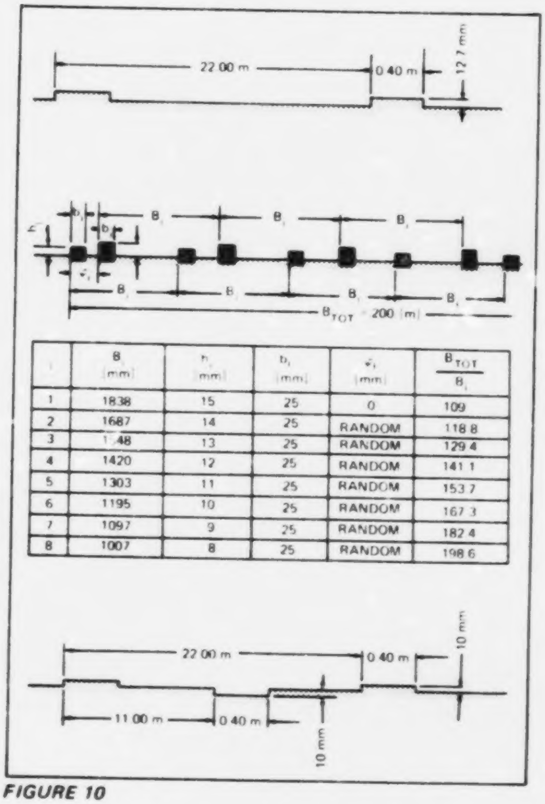
Figure 10 shows the fundamental parameters of such examples.

The discreet values obtained were joined by continuous lines: this is like describing the obtainable Power Spectrum with an infinitesimal subdivision of the frequencies.

In the following table we compare, basing us on the limiting conditions mentioned at point 3.2, the advantages and disadvantages of the two proposed pavings:

Condition	Chance of compliance		Notes
	SOL. A	SOL. B	
C1	sufficient	sufficient	
C2	good	sufficient	
C3	good	good	
C4	good	sufficient	
C5	sufficient	good	
C6	insufficient	insufficient	
C7	nil	insufficient	(*)
C8	good	good	
C9	good	good	

(*) It can be noted that condition C7 cannot be complied with by a rectangular profile, for which the distribution of the amplitude probability density is asymmetric and concentrated around two values only.

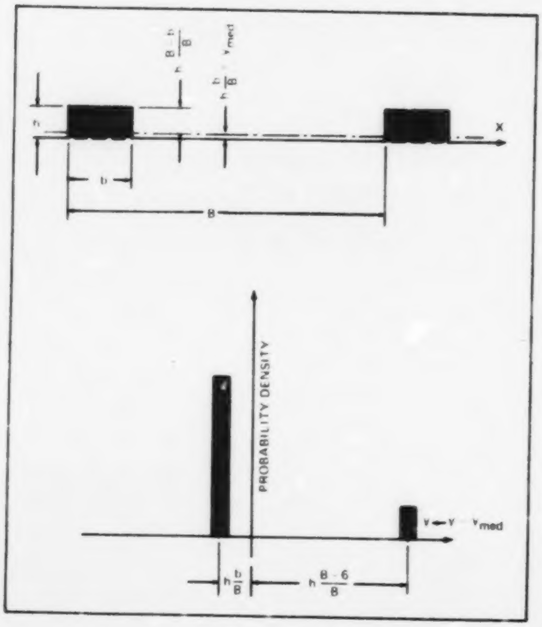

22.00 m
0.40 m
12.7 mm
b_i
B_i
h_i
φ_i
B_{TOT} = 200 [m]
22.00 m
0.40 m
10 mm
11.00 m
0.40 m
10 mm

i	B_i [mm]	h_i [mm]	b_i [mm]	φ_i [mm]	$\frac{B_{TOT}}{B_i}$
1	1838	15	25	0	109
2	1687	14	25	RANDOM	118.8
3	1548	13	25	RANDOM	129.4
4	1420	12	25	RANDOM	141.1
5	1303	11	25	RANDOM	153.7
6	1195	10	25	RANDOM	167.3
7	1097	9	25	RANDOM	182.4
8	1007	8	25	RANDOM	198.6

FIGURE 10

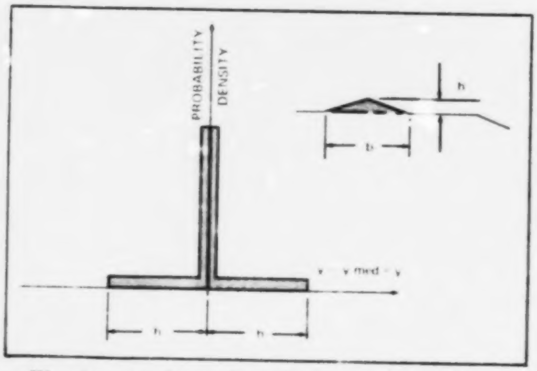
To avoid, at least partially, such disadvantages, it would be better to build obstacles, with the following characteristics:

a) an alternating positioning, a positive and a negative one (sol. C Figs. 9 - 10).


h
b
B
x
$h\frac{B-b}{B}$
$h\frac{b}{B}$
y_{med}
PROBABILITY DENSITY
$y \leftarrow y - y_{med}$
$h\frac{b}{B}$
$h\frac{B-b}{B}$

b) a non-rectangular section (e.g. triangular).

In such case we would have the following probability distribution of the amplitudes.


PROBABILITY DENSITY
h
b
y − y med − y
h
h

We do not deny that there are difficulties in maintaining the efficiency of the negative obstacles, as they would be prone to filling in.

Furthermore we believe that this type of paving is unobtainable in practice, for the case of solution B, because of the very small width b of the obstacles.

Even for solution B, with the same distribution skewness, it is better to use triangular or trapezoidal section obstacles.

With respect to the type of test on the average behavior of the vehicle on rough surfaces, we believe that a transient test (sudden steering action, J turn, etc.) is not suitable to show the vehicle sensibility to surface roughnesses alone, because of weight transfer and roll and yaw oscillations.

Hence we propose in any case a *steady state test*.

More precisely, a steering pad could be used: the vehicle would travel around it a certain number of times, until the max. possible speed is reached. The average speed for the fastest "lap" would then have to be higher than a minimum value legislated for a specified mean radius.

The steering pad could consist of two concentric and adjacent annuli, for which the separating circle would have the mean radius. The internal annulus would have the described obstacles (Fig. 10), positioned radially.

The external annulus would have the same obstacles, out-of-phase with respect to the ones of the internal annulus by an amount linked with the track to be specified, and with the excitation periodicity.

Generally, the out-of-phase of the generic component, should be given by:

$$\psi_k = \pm 2k\pi \frac{C}{L} \text{ radians}$$

where C = track to be specified.
L = total length of the mean circumference (excitation period).

But we have seen that, for the types of paving proposed, the out-of-phase can be chosen for only one component of each series, that is:

$$\psi_i = \pm 2\pi K_i \frac{C}{B_i} \text{ radians}$$

where B_i = fundamental component period.

This means simply that all the series of obstacles in the external annulus will be placed with an out-of-phase of $\pm C/K_i$ on the mean circumference, with respect to the series in the internal annulus. It follows that, for a given internal annulus, there will be 2_n possible external annuli (where n = number of series of obstacles). The solutions with only one series of obstacles (e.g. A and C) are therefore clearly inferior to the ones with more series of obstacles (e.g. B), when judged from the viewpoint of the out-of-phase casuality of excitation between the inner and outer wheels.

Summarizing the contents of this paper, we can say that:

- We believe it is important to verify the vehicle behavior with steady state tests on undulated surfaces.
- The problem of obtaining a testing facility which is easy to build, has good reproducilibity, durability, and efficient real road simulation, is very arduous.
- If approximate solutions are acceptable (and they are fairly acceptable, in our opinion), it is possible to use simplified types of roughness.
- As a contribution to the study of this problem, we have shown two possible solutions, which satisfy, at least in part, the requirements indicated.

THE FIAT TECHNICAL PRESENTATION

DR. OSCAR MONTABONE, *General Vice Director*

INTRODUCTION

At this 3rd International Conference on the E.S.V., FIAT is presenting the results obtained so far in three of the numerous branches it is following in its safety program, namely:

- analysis of road accidents
- Study on the crashworthiness of current production passenger cars
- study of an E.S.V. prototype in the 1200 lbs class

The results on crashworthiness represent the completion of the work whose first results were released at the Stuttgart Conference.

At that Conference a general idea was given of the FIAT safety program, stating that it was a two-stage:

1200 lbs	all rear
1800 lbs	all forward
2200 lbs	front engine, real wheel drive

Now, eight months in advance over the initial program, FIAT is submitting a first study of an E.S.V. prototype in the small, lowcost passenger car field.

We have pushed ahead hard on the 1200 lbs class, as we feel that it is considerably more important than the other two classes.

The work of defining the E.S.V. was subdivided into three phases, each of which encompassed a given number of problems:

1st Survival space, low speed protection, aggressiveness
2nd Occupant protection and passive restraints
3rd Vehicle handling and other active safety characteristics.

The prototype which will be described in our presentation was born of the 1200 lbs class study and has finally ended in the 1500 lbs class. For this prototype, our attention has been confined to the problems in the first group, purposely leaving passive restraint systems aside for the moment.

We have scheduled a total of ten units of this prototype.

Two have already been built, and any defects of design revealed by these two first prototypes will naturally be corrected on the others.

The second- and third-phase problems will be the subject of study for the subsequent series of prototypes that will be developed in the coming months. During the same period we shall make a start on the definition of the E.S.V. in the two other classes: 1800 and 2200 lbs.

The FIAT technical presentation is divided into four parts:

I Analysis of road accidents in Italy
II Completion of the study on production car crashworthiness improvement
III Proposal for changes in E.S.V. impact test specifications
IV First study of the 1.500 lbs class E.S.V.

ANALYSIS OF ROAD ACCIDENTS IN ITALY

The fundamental problem in car safety research is to arrive at a balanced compromise between conflicting technical, economical and safety requirements.

It is, therefore, unrealistic to imagine that a safety car will always ensure overall and absolute protection for the occupants in any type of accident and at any level of severity.

What we can reasonably expect is a good degree of protection in the types of accidents and at the severity levels which are statistically more frequent.

These considerations show just how important it is to make a careful analysis of the information derived from accident research.

At the Stuttgart meeting we reported on the results of a first study based on the data released by the Istituto Centrale di Statistica Italiano.

It is worthwhile recalling the basic points of this report suitably updated to the final 1970 statistics.

Fatalities from road accidents in Italy	10,208 = 100%
Fatalities in accidents where at least one passenger car was involved	7,792 = 76.3%

FIGURE 1

The number of accident fatalities recorded where at least one car is involved is almost equally shared between: the fatalities among car occupants — 3,931 = 50.4% and the fatalities among pedestrians and exposed riders — 3,861 = 49.6%. Fatalities are divided as shown in Figure 2.

Accidents in which cars are involved		No. of deaths	
		Occupants	Pedestrians and exposed riders
Against	other cars	1,292	
Against	trucks, buses and trolley buses	1,109	
Single car		1,530	
Against	bicycles, mopeds, motorcycles		1,808
Pedestrians			2,053
Totals		3,931=50.4%	3,861=49.6%
		7,792	

FIGURE 2

This is the situation in Italy.

In other countries the situation is not radically different, as demonstrated by the data obtained from the official statistics of the European Economic Community, from those of the European Economic Commission of the United Nations, and from U.S. statistics.

The data from these publications are not always comparable with the Italian data, and it is to be hoped that agreement will shortly be reached on international unification of the criteria for recording and classification.

In particular, in some cases the data relevant to the fatalities among pedestrians and exposed riders are not always available for comparison to the number of deaths where only cares are involved.

To obtain a clear comparison at international level, we considered both car occupant fatalities and the fatalities among pedestrians and exposed riders; and we took for comparison not only the accidents in which cars are involved, but all road accident deaths, however caused, as shown in Figure 3.

Considered in this way the percentage of car occupant fatalities ranges from a minimum of 38.4% in the United Kingdom to a maximum of 63.5% in the U.S.A. while the fatalities among pedestrians and exposed riders have their minimum — 26.2% — in the U.S.A. and maximum — 54.1% — in the U.K. In 1969 these percentages were: car occupant fatalities from a minimum of 35.5% in the United Kingdom to a maximum of 66% in the U.S.A. whereas the fatalities among pedestrians and exposed riders ranged from a minimum of 25.5% in the U.S.A. to a maximum of 56.3% in the United Kingdom.

These data call for reflection on two basic points:

1. The great importance of the problem of vehicle aggressiveness toward other road users, especially pedestrians and exposed riders.
2. The limited effect of the measures aimed at occupant protection. These measures, in fact, can have positive consequences only on a percentage of victims which, for the countries indicated in the chart of Figure 3, averages out at around 55%.

In this connection we feel it is of interest to submit to your attention the average (taking 13 Countries of Western EUROPE) of the ratio between the fatalities among car occupants and the total fatalities in all road accidents.

The European average, as shown in Figure 4, drops down to 42.3%.

COUNTRY	Italy		U.S.A.		W. Germany		France		United Kingdom	
	1969	1970	1969	1970	1969	1970	1969	1970	1969	1970
Total Deaths in Road Accidents	9,891	10,208	56,400	54,800	16,646	19,177	14,664	15,340	7,363	7,499
Passenger Car Occupant Fatalities	3,639 46.8%	3,931 38.5%	37,240 66%	34,820 63.5%	7,534 45.3%	8,987 46.9%	7,285 49.7%	7,522 49%	2,617 35.5%	2,877 38.4%
Exposed Riders and Pedestrian Deaths	57.8%	57.3%	23.5%	26.2%	50.5%	61.2%	46.2%	47.3%	56.3%	54.1%
Bicycles, Mo-peds, Motorcycles	3,188 32.2%	3,200 31.3%	3,430 6.1%	3,920 7.2%	3,206 19.3%	3,782 19.7%	3,654 24.9%	4,044 26.4%	1,193 16.2%	1,134 15.1%
Pedestrians	2,533 25.6%	2,651 26%	9,800 17.4%	10,400 19%	5,199 31.2%	6,043 31.5%	3,117 21.3%	3,202 20.9%	2,954 40.1%	2,925 39%

FIGURE 3

WESTERN EUROPE

Austria	Percentage of car occupant fatalities VS. road accident fatalities 42.3%
Belgium	
Denmark	
Finland	
France	
German Federal Republic	
Italy	
Norway	
Netherlands	
Portugal	
United Kingdom	
Sweden	
Switzerland	

FIGURE 4

As we said earlier, the analysis of road accidents is of fundamental interest, for an accurate understanding and evaluation of safety problems.

However, the official Italian statistical data are not sufficient for a complete evaluation of the type, frequency and characteristics of road accidents.

To acquire this type of information and to get a better understanding of the man-car system in accidents, we too, like other manufacturers, felt the need of making a direct investigation of actual accidents. This investigation was started only recently.

LOCATION OF FIAT ACCIDENT INVESTIGATION CENTERS

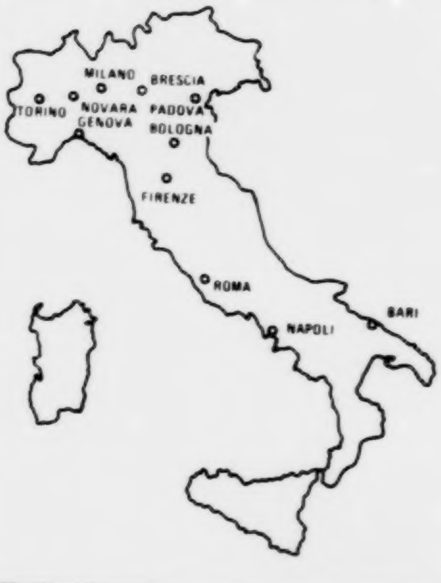


FIGURE 5

So far we have examined 410 cars involved in crashes, and the analysis of the relevant data is in course of completion.

Our investigation form is a simplified version of the Forms adopted by various Bodies such as Cornell, General Motors, NATO and the French ONSER and is accompanied by photographs of car damage and indications of occupant injuries.

We established 11 Accident Investigation Centers distributed over an area accounting for about 40% of the total number of cars on the road and 50% of the total number of accidents (Figure 5).

Our investigation refers to accidents to FIAT cars only (Figure 6); this does not invalidate the reliability

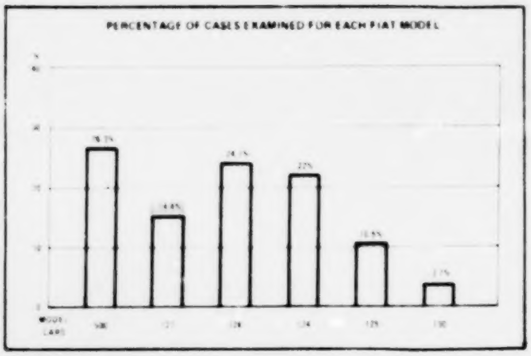


FIGURE 6

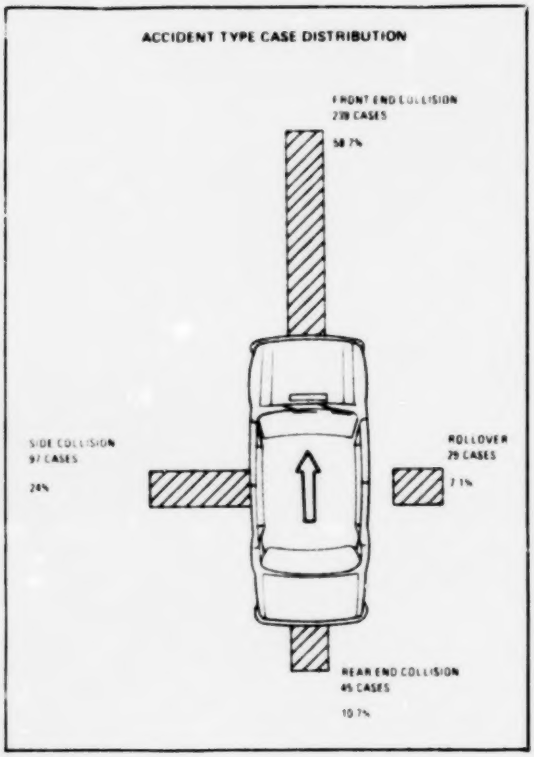

ACCIDENT TYPE CASE DISTRIBUTION
FRONT END COLLISION
239 CASES
58.7%
SIDE COLLISION
97 CASES
24%
ROLLOVER
29 CASES
7.1%
REAR END COLLISION
45 CASES
10.7%

FIGURE 7

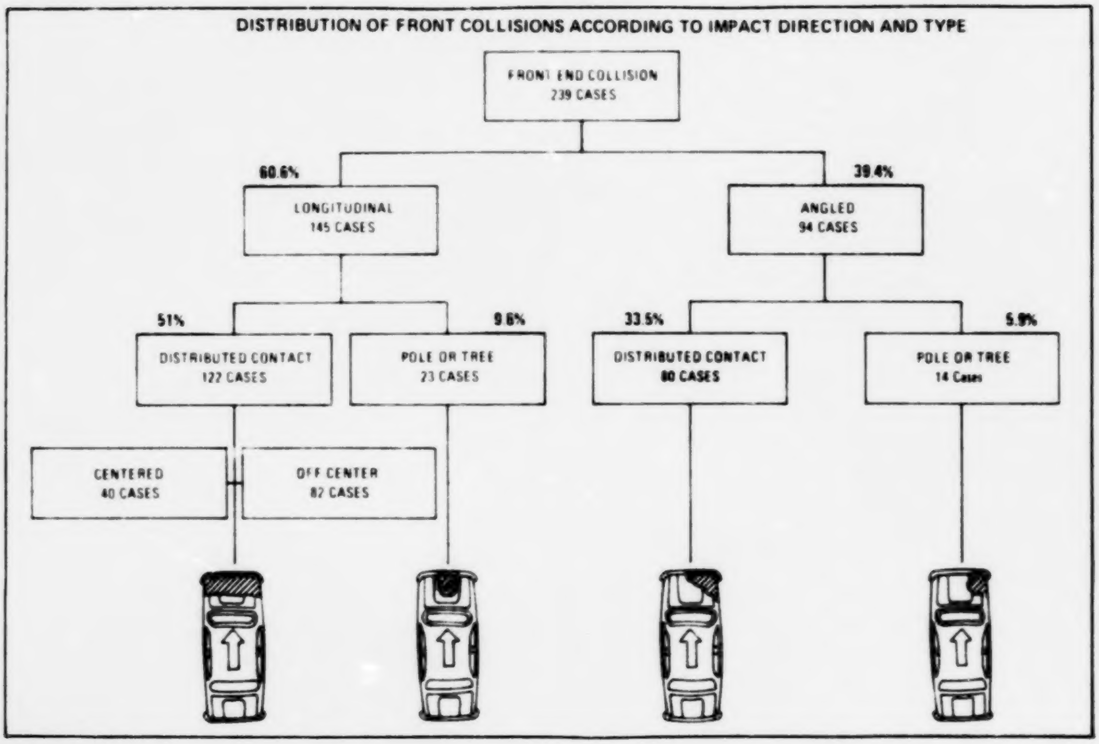

DISTRIBUTION OF FRONT COLLISIONS ACCORDING TO IMPACT DIRECTION AND TYPE
FRONT END COLLISION
239 CASES
60.6%
LONGITUDINAL
145 CASES
39.4%
ANGLED
94 CASES
51%
DISTRIBUTED CONTACT
122 CASES
9.6%
POLE OR TREE
23 CASES
33.5%
DISTRIBUTED CONTACT
80 CASES
5.9%
POLE OR TREE
14 Cases
CENTERED
40 CASES
OFF CENTER
82 CASES

FIGURE 8

of the sample as to its representativeness of the situation in Italy, inasmuch as FIAT cars here account for about 70% of all cars on the road and represent a widely diversified range.

In a first subdivision we analyzed the accidents according to collision type: front end, rear end, side, and rollover. (Figure 7)

The most frequent type of accident is the front end collision (58.2%) whereas rollover is the least frequent (7.1%).

Front end collision

Let us now examine the front end collisions (239 cases) in more detail (Figure 8):

It is immediately apparent that longitudinal impacts represent 60.6% of the total while angled impacts account for 39.4% only.

In 84.5% of the cases the contact is distributed over a wide area (impact against other vehicles) and only in 15.5% of cases is it concentrated (for example, impact against a pole).

Rear end collision

Figure 9 shows rear end collision distribution according to impacted direction and type. In rear collisions, too, longitudinal impacts predominate (91.1% of cases).

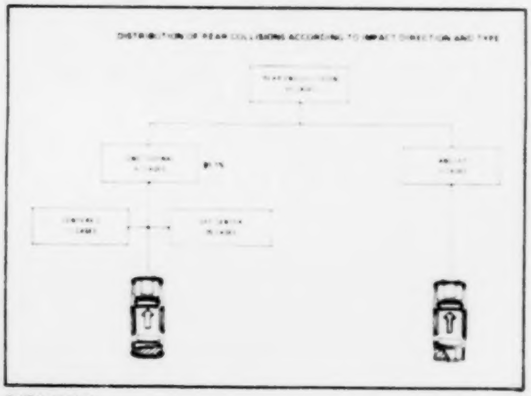

DISTRIBUTION OF REAR COLLISIONS ACCORDING TO IMPACT DIRECTION AND TYPE

FIGURE 9

Side collision

In this type of accident, the impact occurs in the passenger compartment area in only 44.3% of cases, while in 55.7% it occurs elsewhere (Figure 10). With this type of accident, as for front collisions, 83.5% of cases can be attributed to impact against other vehicles while 16.5% consist of concentrated impacts (Figure 11).

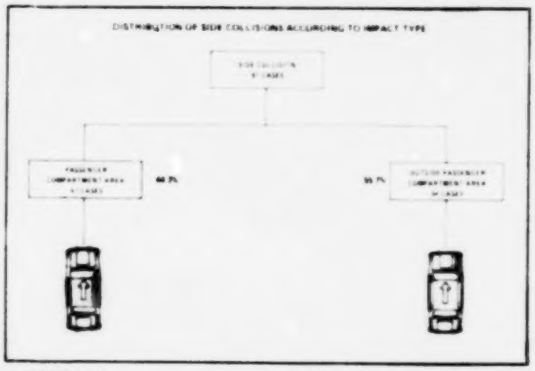

DISTRIBUTION OF SIDE COLLISIONS ACCORDING TO IMPACT TYPE
PASSENGER COMPARTMENT AREA
OUTSIDE PASSENGER COMPARTMENT AREA

FIGURE 10

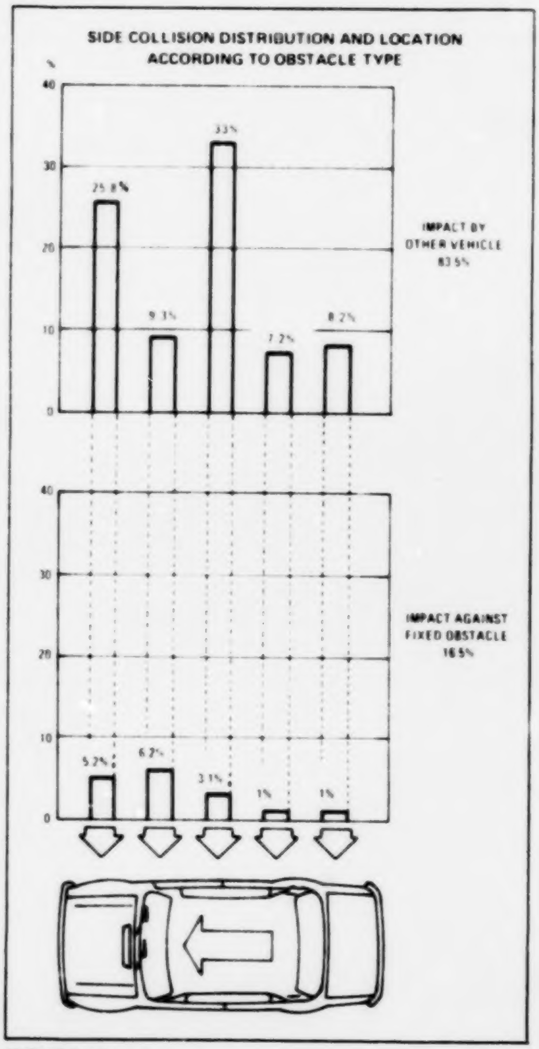


FIGURE 11

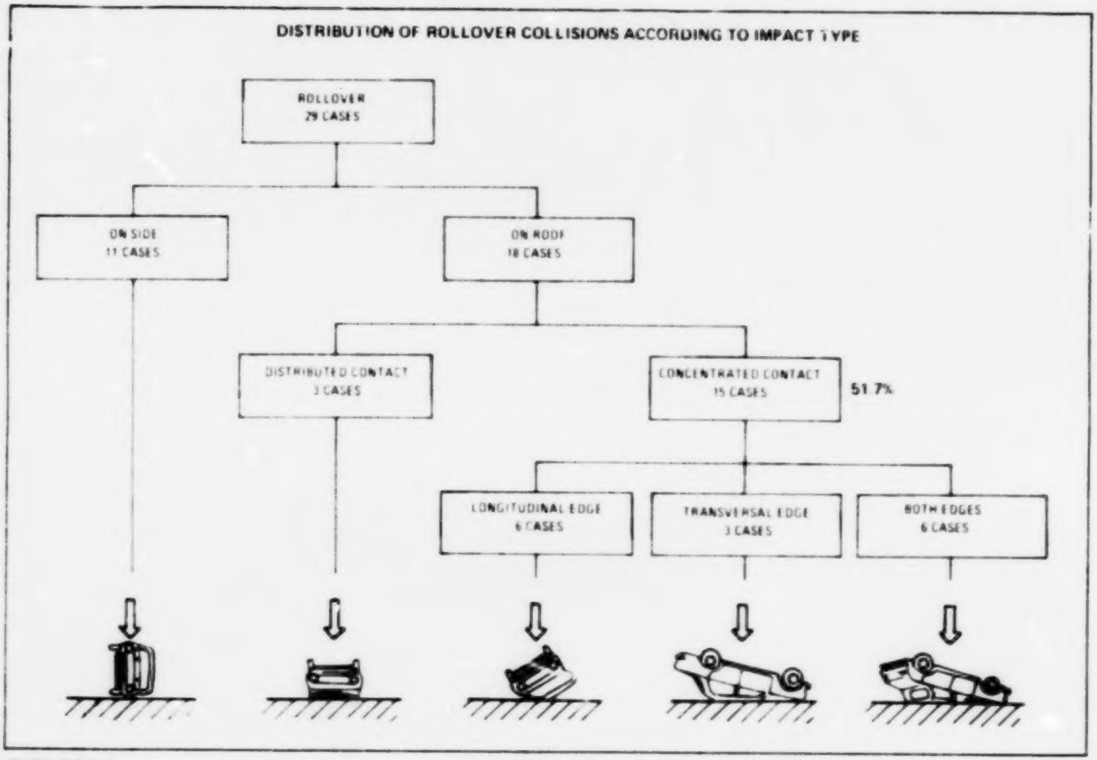

DISTRIBUTION OF ROLLOVER COLLISIONS ACCORDING TO IMPACT TYPE

FIGURE 12

Rollover

In the 29 cases analyzed (Figure 12) overturning onto the roof, with concentrated contact, represents about 51.7%.

Let us now evaluate vehicle damage.

It has been rated according to the five severity levels of the Cornell Aeronautical Laboratory ACIR scale (Figure 13).

Distribution is clearly Gaussian (Figure 14). It should however be noted that light accidents have not been taken into account.

The same distribution occurs for each type of accident, for each of which the maximum concentration is at moderate to severe levels (see Figure 15).

Given the very small number of accidents investigated, we are not yet in a position to draw any conclusions as to the type of accident which causes the most severe damage to the vehicle.

Let us now examine injuries to occupants:

The number of occupants in the 410 damaged cars investigated was 697, giving an average occupant density of 1.7 per car (Figure 16).

81.7% of the accidents occurred with one or two persons aboard (Figure 16).

The accident consequences on car occupants were rated according to three severity levels:

- no injuries, or contusions only
- injuries
- fatalities

Distribution of the severity levels is shown in Figure 17.

59.1% of the occupants in the 410 damaged cars were uninjured or only cut and bruised.

As to the dangerousness to occupants of the various types of accidents, we think some conclusions may already be drawn, in spite of the still small number of cases examined.

In the histograms (Figure 18) the total number of uninjured, injured and dead occupants, has been sub-divided according to the type of accident.

The percentage of injured persons in front collisions is twice the percentage of the total in the other three types of accidents combined whereas the percentage of fatalities is instead equal to that caused cumulatively by the other three types of accidents.

We have divided the severity levels of damage to persons in the front collisions, which are those

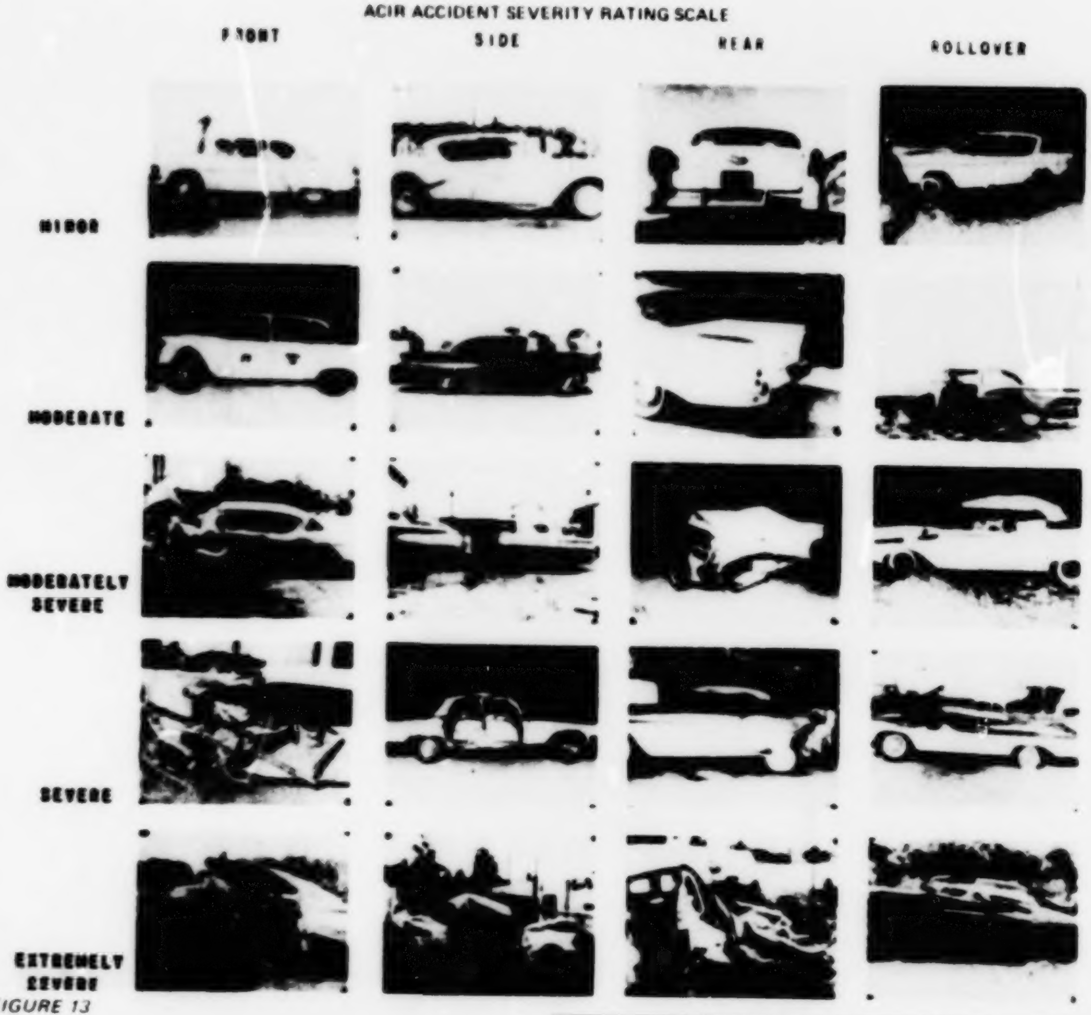

ACIR ACCIDENT SEVERITY RATING SCALE
FRONT
SIDE
REAR
ROLLOVER
MINOR
MODERATE
MODERATELY SEVERE
SEVERE
EXTREMELY SEVERE

FIGURE 13

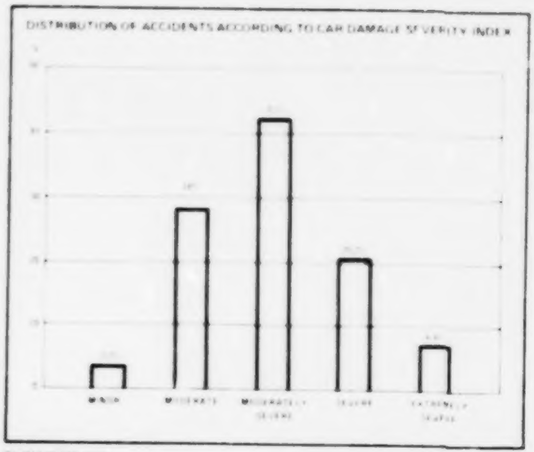


FIGURE 14

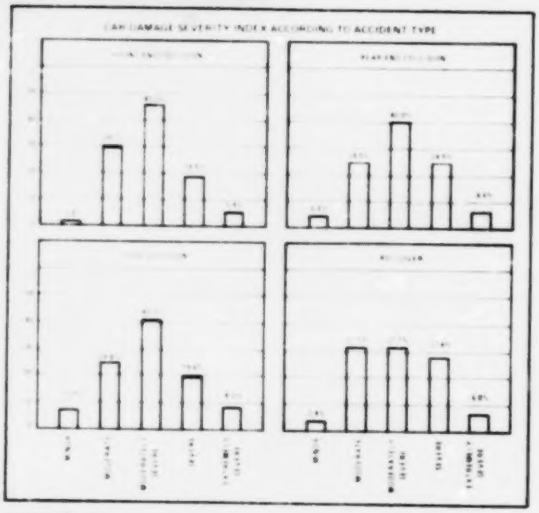


FIGURE 15

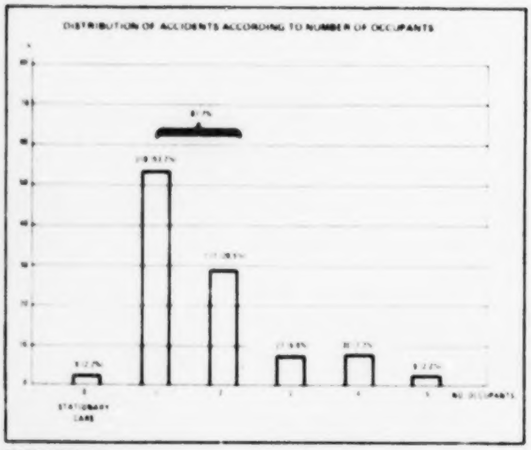


FIGURE 16

occurring at a higher frequency, have been subdivided according to the direction of impact of type of obstacle.

In front collisions, most of the injuries are caused by longitudinal rather than angled impacts (Figure 19).

If, on the other hand, the type of obstacle is considered, the number of injuries caused by impact against another vehicle turns out to be much higher than when the impact is against an obstacle such as a pole or tree (Figure 20).

Conversely, in side impacts, injuries are evenly distributed between impacts in the passenger compartment area and impacts in the other side areas (Figure 21).

In side collisions too, the number of injuries caused by impacts against other vehicles is much

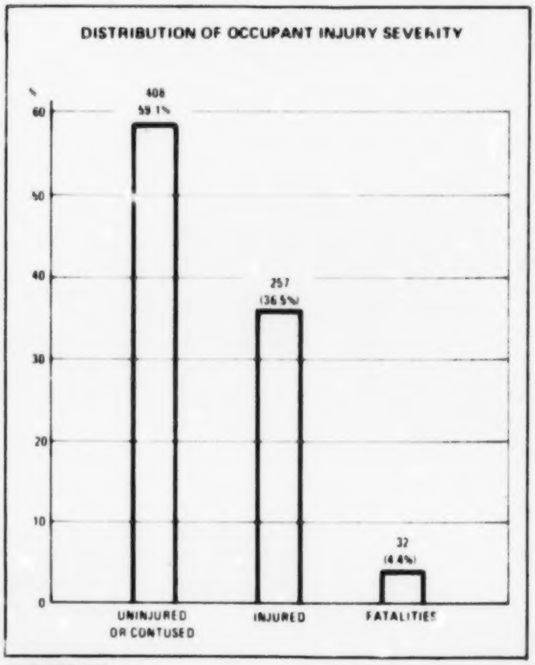


FIGURE 17

higher than impacts against small fixed obstacles (Figure 22).

If a conclusion is required concerning the severity level of the various types of accidents, frequency not being taken into account, it appears that front collisions are the most severe type of accident: only 56% of car occupants came out uninjured or bruised, as compared to over 60% in the other types of impacts (Figure 23).

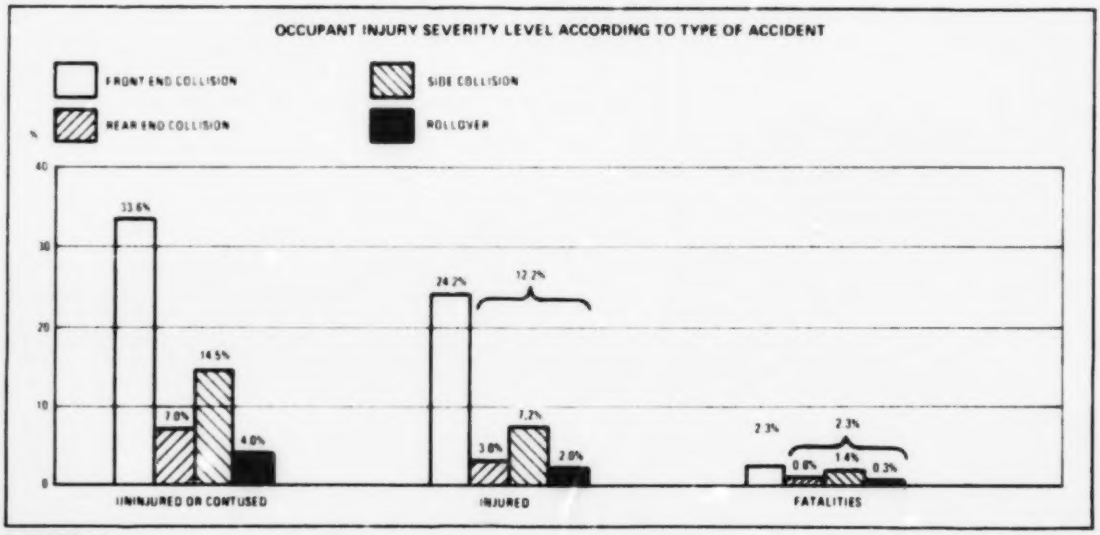


FIGURE 18

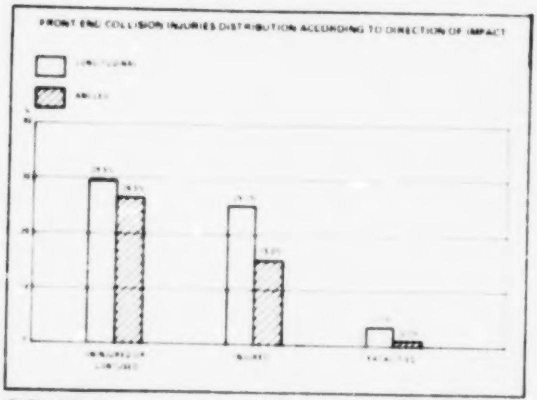


FIGURE 19

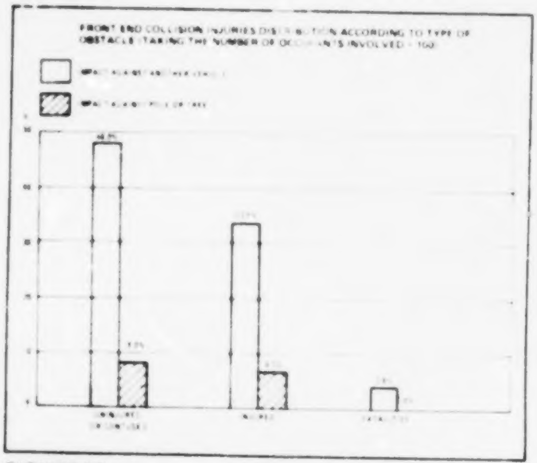


FIGURE 20

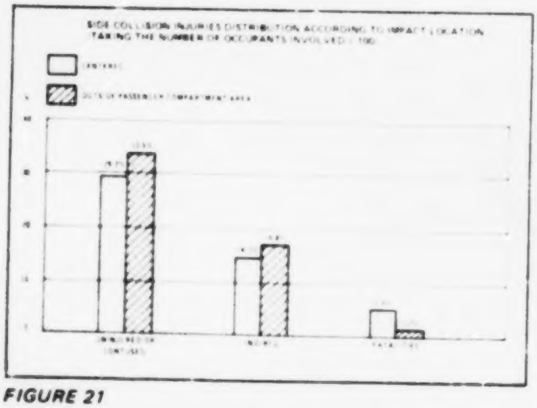


FIGURE 21

We think it is also useful to compare the severity of occupant injury with the degree of damage to the vehicle.

Even if we consider the 110 cars in which the damage was rated as "severe" or "extremely severe" (83 and 27 respectively) the number of uninjured or contused occupants is still 38% (Figure 24).

To sum up what has been said so far, the accidents, which cause most of the injuries are front collision with another vehicle.

We wish to point out again that what we have said is subject to some variation, due to the limited number of cases examined.

Reliable data will be available only after the investigation has been extended to some thousands of accidents.

However, we do not think that the picture we have just given is likely to vary to a great extent, as the new data which have come in recently have not considerably affected the results obtained from a sample equivalent to about one third of the present one.

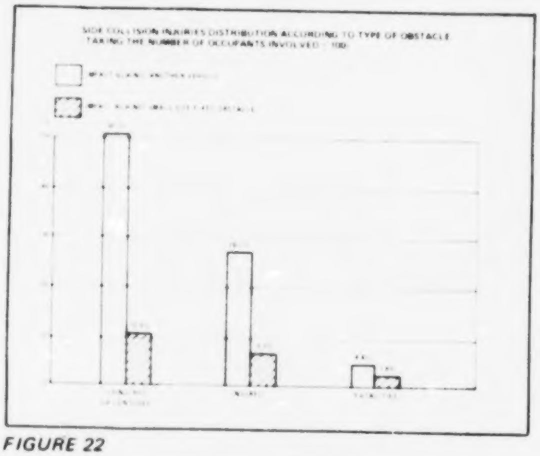


FIGURE 22

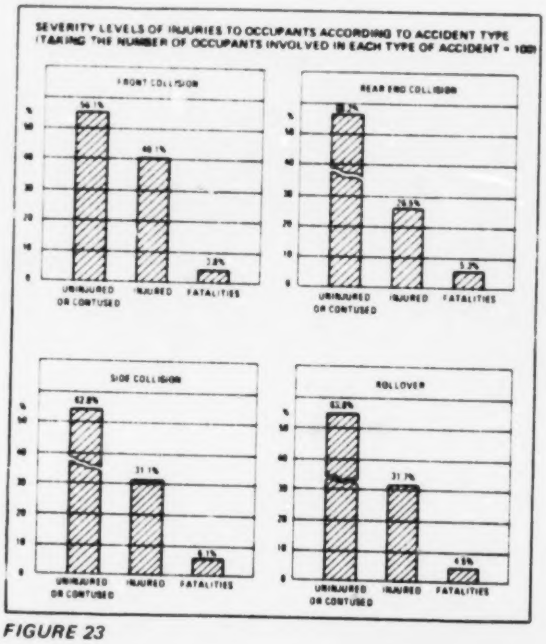


FIGURE 23

DISTRIBUTION OF OCCUPANT INJURY SEVERITY IN CARS AT "SEVERE – EXTREMELY SEVERE" DAMAGE INDEX

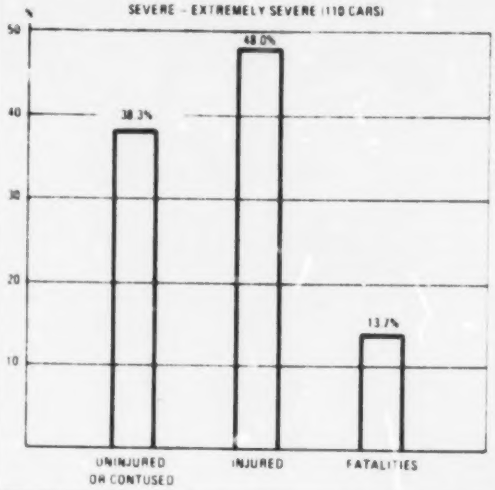


FIGURE 24

COMPLETION OF THE STUDIES ON PRODUCTION CAR CRASHWORTHINESS IMPROVEMENT

At the second conference in Stuttgart some advance information had been given on the test work being conducted on the three different types of cars chosen by FIAT for investigation.

Now that the testing cycle is over, it is possible to have a general outline of the results obtained.

For the evaluation of the behavior in collisions of original and modified cars belonging to the three weight classes under investigation, FIAT selected those of the American E.S.V. specification test, which, in its view, offered greater significance, namely:

- 50 mph front end collision against barrier
- 50 mph front end collision against pole
- 50 mph rear end collision by moving barrier
- 15 mph side collision against pole
- Rollover.

Angled collisions, both front and rear, have been purposely left aside for the reasons that we will lay down in the report *Proposal for changes in E.S.V. impact test specifications*.

What we want to stress is that, as already said in Stuttgart, in this first research stage, only the problem of the survival space was dealt with, because it was an essential condition in providing sufficient protection for occupants.

Front end collisions against barrier

Passenger compartment average decelerations in the 50 mph collision test using reinforced cars in the 1,200 and 2,200 lb. classes – already presented in Stuttgart – were 96 and 100 g respectively whereas steering wheel rearward displacements were 2.91 and 4.2 inches.

Subsequently, a collision test was performed on the 1,800 lb. class car. A passenger compartment average deceleration of 64 g and a steering wheel rearward displacement of 5.74 inches were measured on this car.

Also in this case, the scope was attained of ensuring a satisfactory integrity of the passenger compartment in a 50 mph impact (Figure 1), same as is now the case with the standard production car impacted at 30 mph (Figure 2).

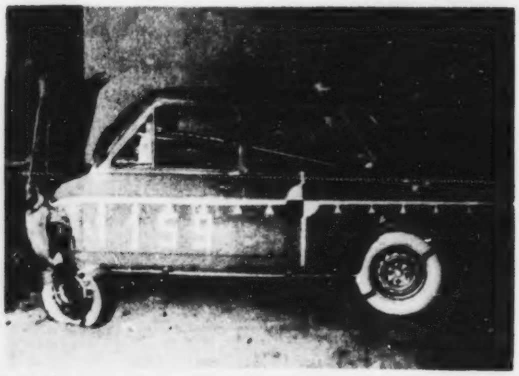


FIGURE 1

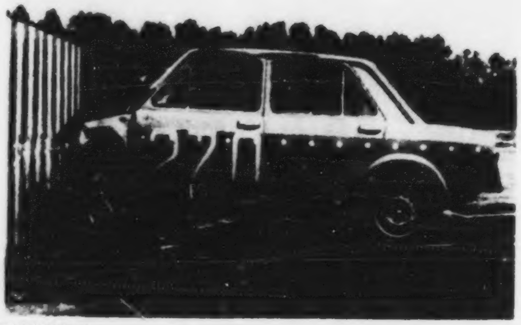


FIGURE 2

Front end collisions against pole

Front end collisions against a pole at 50 mph must be regarded as the severest test required by E.S.V. specifications, especially if the standpoint of survival space retainment is to be preserved.

The results of the tests carried out only on reinforced cars in the three classes is illustrated in Figures 3, 4 and 5 relevant to the 1,200, 1,800 and 2,200 lb. cars; average passenger compartment decelerations were 70, 58 and 55 g respectively.

The cars showed passenger compartment intrusion values which are unacceptable under the above mentioned standards in spite of subsequent modifications.

In our opinion, the severity level of these tests is too high.

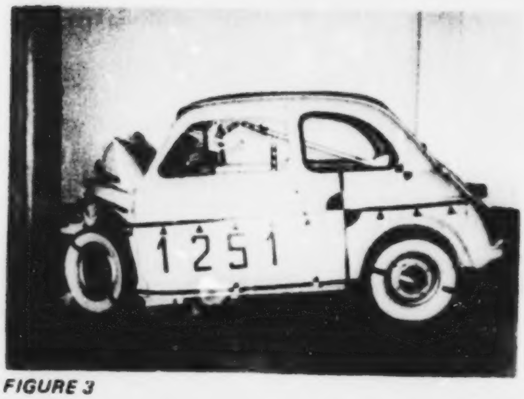


FIGURE 3

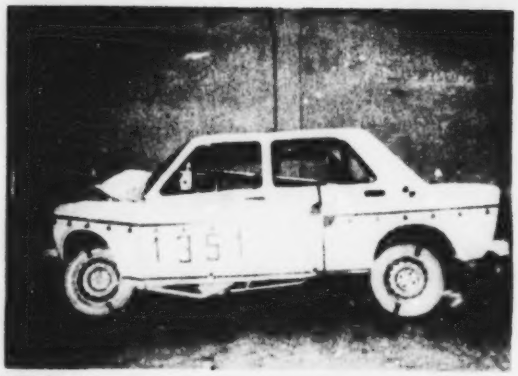


FIGURE 4

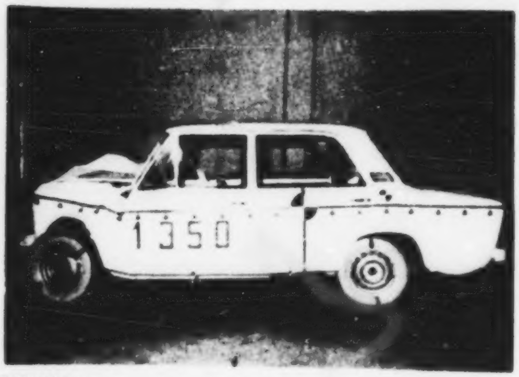


FIGURE 5

Rear end collisions

Maximum passenger compartment intrusion for the 1,200 lb. reinforced car involved in a rear end collision with a moving barrier at 50 mph was 2 inches, which is well within the limit allowed by the E.S.V. specifications (Figure 6).

In the 2,200 lb. reinforced car rear-end collision test, deformations were confined to the rear section of the body, while the interior space remained practically unchanged (Figure 7).

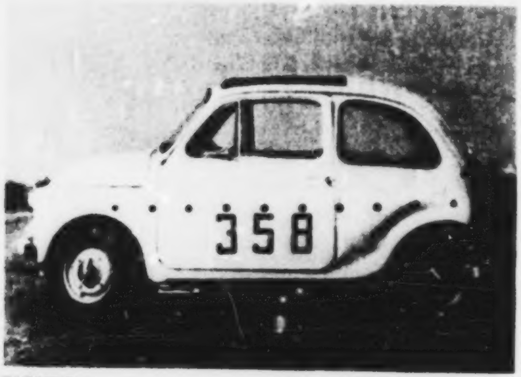


FIGURE 6

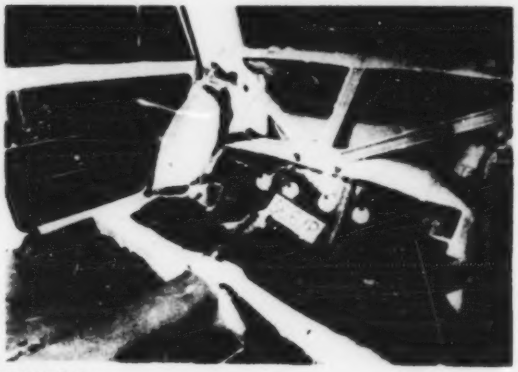


FIGURE 7

Side collisions against pole

After carrying out a preliminary series of 15 mph tests on current production cars, the same tests were repeated on the 1,200 and 1,800 lb. reinforced cars (Figures 8, 9). In order to leave the architecture and

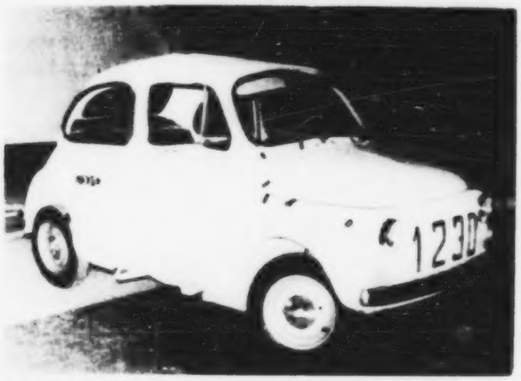


FIGURE 8

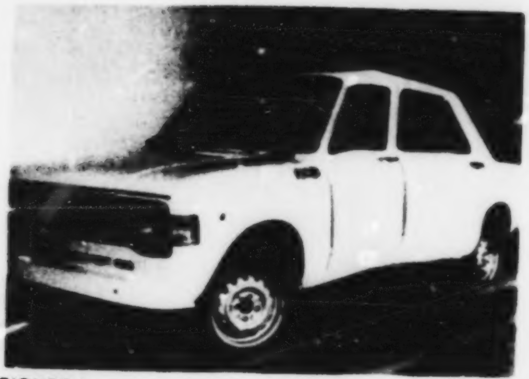


FIGURE 9

the overall width of the body unchanged, only local reinforcements were added, yet no appreciable benefits were obtained.

On the 2,200 lb. car (Figure 10), instead, we succeeded in containing penetration within the limit indicated in the E.S.V. specification.

The maximum penetration values recorded are 2.91 inches on the pillar and 3.75 inches at door center.

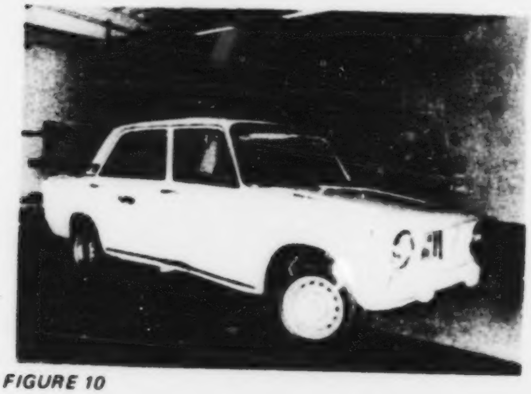


FIGURE 10

Rollover

As an alternative procedure to rollover tests, the 2 foot drop test was adopted as it was more easily reproducible while reflecting rollover effects quite faithfully (Figure 11).

The car is positioned, according to the specified angles, by means of cables. a quick release mechanism ensures that trim remains unchanged when car is released.

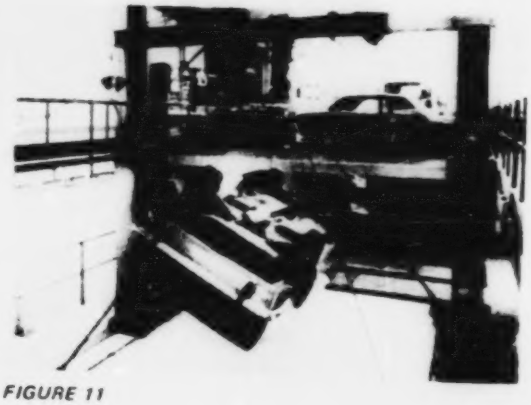


FIGURE 11

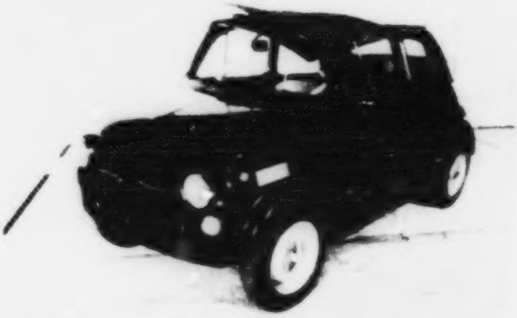


FIGURE 12

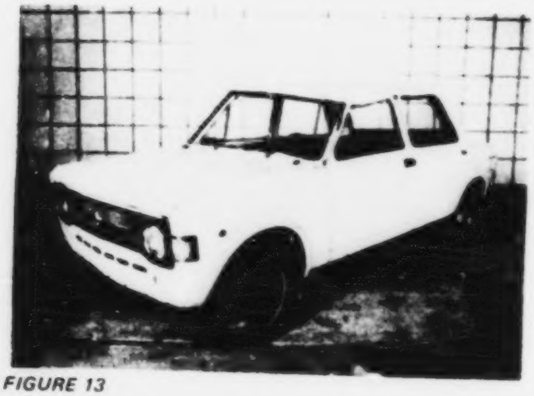


FIGURE 13

The results obtained from current production cars are shown in Figures 12, 13 and 14. In these tests, measured intrusions were 7.9, 4.3 and 7.4 inches.

No tests were run on reinforced cars as it was felt that, with minor and easily envisageable modifications, the maximum deformation requirement specified for the E.S.V. can be met.

CONCLUSIONS

These results completed the cycle of tests on reinforced current production cars.

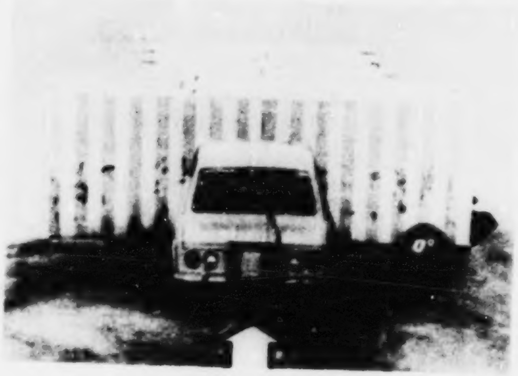
The indications so far obtained provide sufficient information for the design of the first prototype of experimental safety car.

FIGURE 14

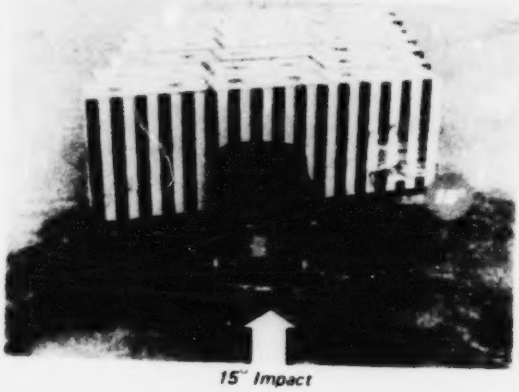
PROPOSAL FOR CHANGES IN E.S.V. IMPACT TEST SPECIFICATIONS

The E.S.V. specifications require that the front, high speed barrier collision tests be carried out at angles, between the normal to the barrier face and vehicle trajectory, of 0° and 15° in the 50 mph test and 45° in the 30 mph test (Figure 1).

From many tests carried out during these last months, in accordance with the above procedure, we have clearly seen that some of these tests have actually little significance, and that a change of present specifications is advisable.



0° Impact



15° Impact

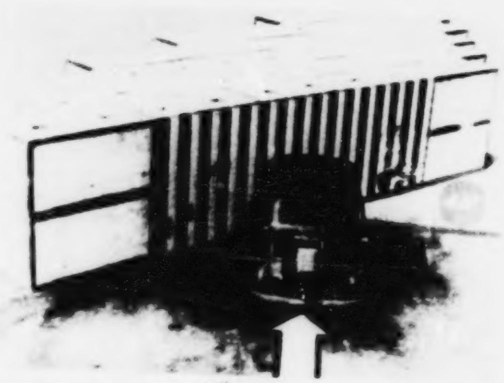
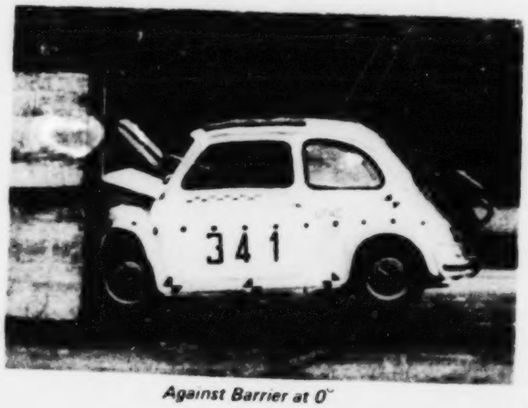
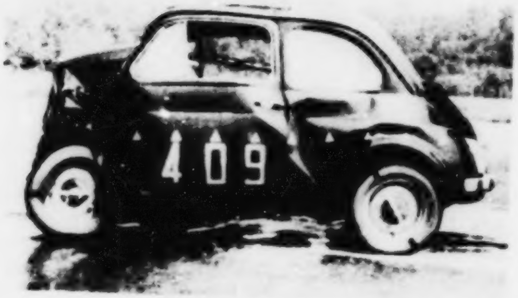


FIGURE 1 *45° Impact*



Against Barrier at 0°



Against Barrier at 15°

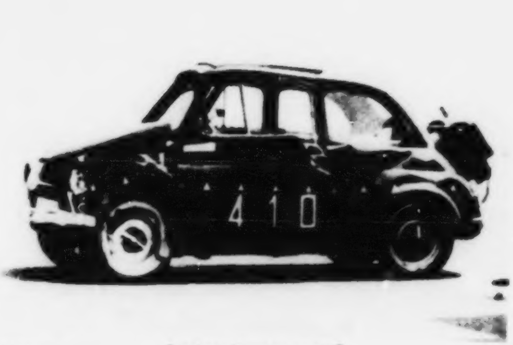
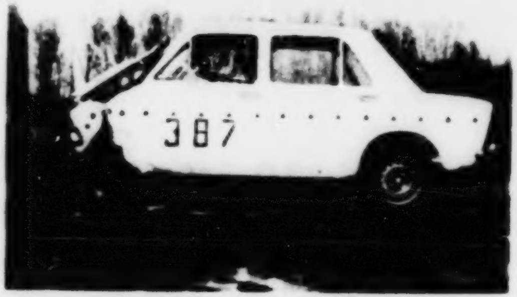


FIGURE 2 *Against Barrier at 45°*

To better clarify our standpoint, we show here the results obtained on a set of our current production cars, in 1200-1800 and 2200 lb. classes, submitted to a front impact against barrier at 0 and inclined at 15 and 45 degrees. For purposes of comparison all the tests were run at 30 mph.

Figures 2, 3 and 4 show the damages suffered by the three vehicles in the three different collision types.

Against Barrier at 0°



Against Barrier at 15°

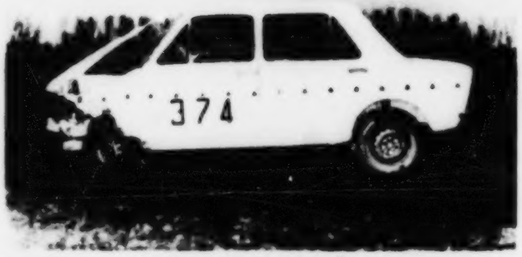
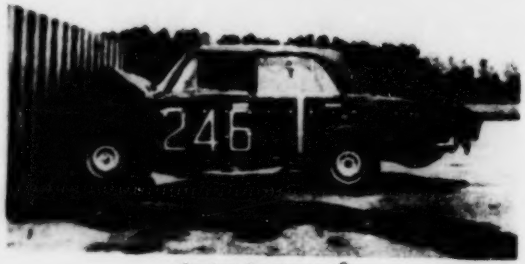
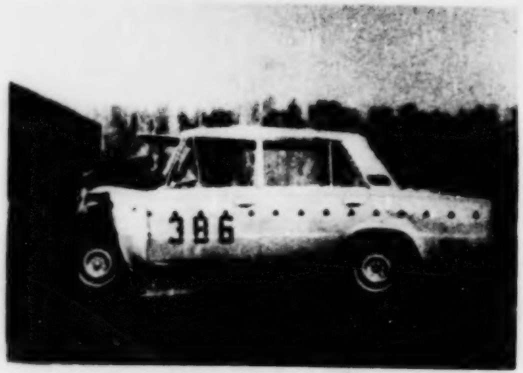


FIGURE 3 *Against Barrier at 45°*



Against Barrier at 0°



Against Barrier at 15°

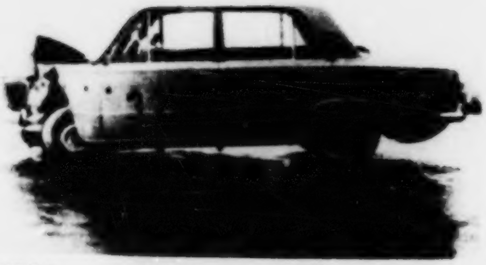


FIGURE 4 *Against Barrier at 45°*

The histograms, in Figure 5, show the data relevant to car shortening and to intrusion of instrument panel and footboard into passenger compartment recorded in different cases.

By examining the histograms in detail concerning the 1200 lbs. class car and by taking the deformations detected in the impact against barrier at 0° as a basis, it can be observed that:

- In the impact against barrier inclined at 15°, the shortening on the right side.

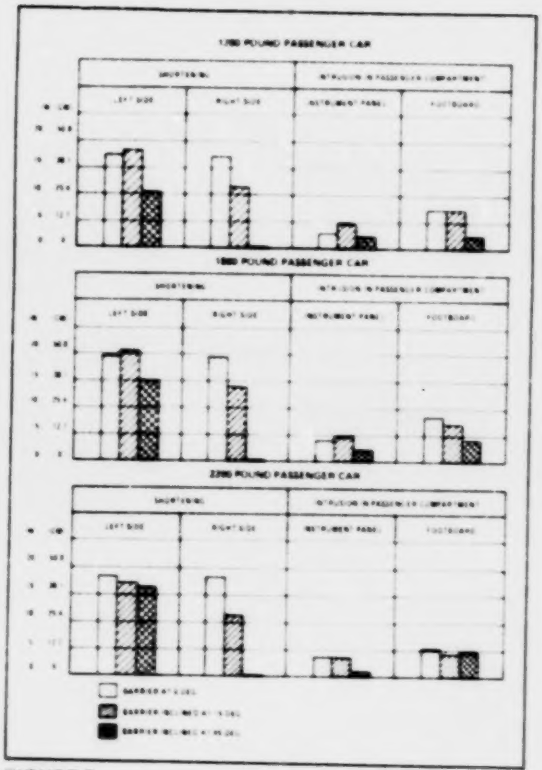


FIGURE 5

- In the impact against barrier inclined at 45°, the shortening on the left side is reduced considerably while the right side is unaffected; footboard intrusion in the passenger compartment is reduced to one third.

From the histograms concerning the 1800 lbs. car, still taking the deformations detected in the impact against barrier at 0° as a basis, it can be observed that:

- In the impact against barrier inclined at 15°, vehicle shortening on the left side is substantially unchanged, whereas shortening on the right side decreases by approximately 30%.
- In the impact against barrier inclined at 45° all the four parameters measured have decreased considerably. In particular, passenger compartment intrusion by the instrument panel and footboard is reduced by approximately 50% compared with the previous impacts.

Finally, by examining the histograms concerning the 2200 lbs. class car with the same comparison criteria used in the above two cases, it can be observed that:

- In the impact against barrier inclined at 15°, the parameters, except for the shortening on the right side which is considerably less, are substantially unchanged.
- In the impact against barrier inclined at 45°, the shortening on the right side is completely unaffected and the instrument panel intrusion in the passenger compartment is greatly reduced.

As a conclusion, it can be stated that with speed at par, the consequences of the impact against barrier at 45 degrees are less severe than those at 0 and 15 degrees.

This is due to the fact that part of the energy is dissipated through the sliding action along the barrier.

On the other hand, the impact at 15 degrees does not yield data significantly different from those of the 0 degree impact.

The same considerations hold good in the case of rear impacts. We therefore tend to feel that tests at 15 and 45 degrees are of no practical use.

Furthermore, remembering what we said both in the accident analysis section and in the section covering the test on reinforced production cars, we feel that the front impact test against a pole is too severe since in our opinion it could be carried out at a speed appreciably lower than specified for a front collision.

Therefore, we propose:

1) The elimination of front and rear impact tests at 15° and 45°.
2) A reduction in the severity of the front impact test against a pole.

A FIRST STUDY OF THE 700 KG (1500 LBS.) CLASS EXPERIMENTAL SAFETY VEHICLE

In October of 1971 work was started on the third phase of our programme: the design and manufacture of a first series of 700 kg Experimental Safety Vehicle prototypes.

This was made possible by the early completion of the second phase of studies and experiments aimed at improving the crashworthiness of the 500 model sedan — the smallest car in the FIAT current production range.

1st Stage
Test on the Fiat 500 model
2nd Stage
Project design, development and testing of modified Fiat 500 model
3rd Stage
Project design, development and testing of preliminary prototypes of the 1,500 lb. (700 kg) experimental safety car
4th Stage
Project design, development, and testing of final prototypes of 1,500 lb. (700 kg) safety experimental car

The objectives set for this project were as follows:

- Definition of car body structure characterisites to ensure a survival space in typical high speed collisions and rollovers.
- Definition of a car body front and rear protection system for low-speed collisions.
- Study of the aggressiveness problem, with particular regard to pedestrians and exposed riders.
- Evaluation of the degree to which the three previous items affect cost and weight.

As regards car body structural characteristics, a large number of tests conducted during the second phase of work on suitably modified FIAT 500 type cars showed clearly that satisfactory behavior in high speed impacts is perfectly possible, even in the case of extremely small sedans.

This, at any rate, as far as preservation of vital passenger space is concerned (Figures 1 and 2).

It was, therefore, a matter of applying in the third phase of the work, the experience already gained to the design of new bodywork, conceived for safety and fitted to the same mechanical components as those of the car previously developed.

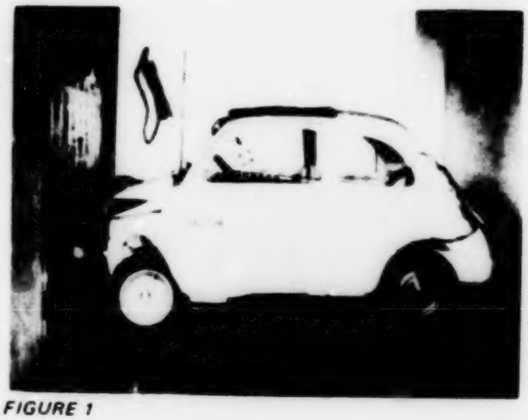


FIGURE 1

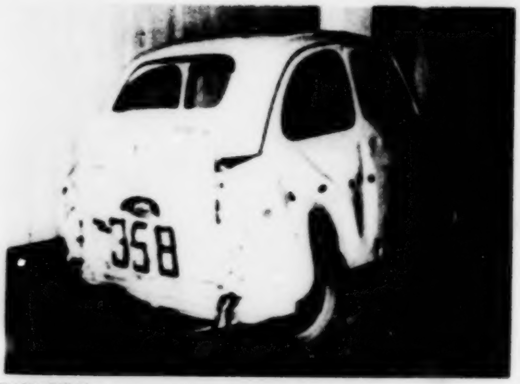


FIGURE 2

In order to maintain the realistic trend — considered as the basis of the whole FIAT safety research program — followed initially in the studies, it was decided to preserve the traditional technical and technological criteria of current mass production.

This in spite of the essentially experimental aims of the work.

Use of standard materials
Adoption of traditional construction methods and technologies

To obtain the second and third objectives, namely front and rear car body protection and reduction of aggressiveness, preliminary studies and tests carried out up to that time had already yielded a number of interesting pieces of information which also made clear the necessity of a combined study of the two problems.

In other words, since the protection system itself played an important role as far as aggressiveness was concerned, the more logical solution was to incorporate into it not only inherent safety features for pedestrians and exposed riders, but also provisions aimed at minimizing car front and rear end overall aggressiveness, above all towards unprotected persons.

As already stated before, the final objective was the accurate determination of cost and weight increase due to three factors: survival space, low speed protection and reduction in aggressiveness.

The 500 sedan was taken as the basis of reference.

The new car was to follow, as much as possible, the original technical and commercial lines.

A first evaluation of weight and cost increases limited to the "survival space" had already been made at the end of the second research phase and has led to rather disappointing conclusions as to the practical validity of the technical results obtained.

However, there was a legitimate doubt that the cost of safety – considered as one of the fundamental elements in the project and not as an accessory item to be introduced at the end – might actually be less high.

It was thus proved absolutely necessary to investigate the point further.

It seems pointless to emphasize once again the importance of a preliminary cost analysis of the different car safety sub-systems.

It certainly does not stem from economic considerations, but rather from the observation that, after all, the most serious limit to the solution of safety problems is the attainment of reasonable cost/benefit ratios.

Before going into the negineering details of our first 700 kg Experimental Safety Vehicle, it is appropriate to provide some interesting data on the FIAT 500 model sedan (Figure 3), which is at the origin of the research in question.

This car is a small, economy 4-seater sedan of the 550 kg class with integral construction, 2-door bodywork, and a rear-mounted 500 c.c., two-cylinder engine.

The 500 sedan has been in production since 1957. So far, over 3.800.000 unites have been manufactured.

In 1971, registrations of this model amounted to 23.3% of the total in Italy (Figure 4).

These figures give a good idea of the position of this car, at the lower limit of the low cost bracket in the Italian popular car range.

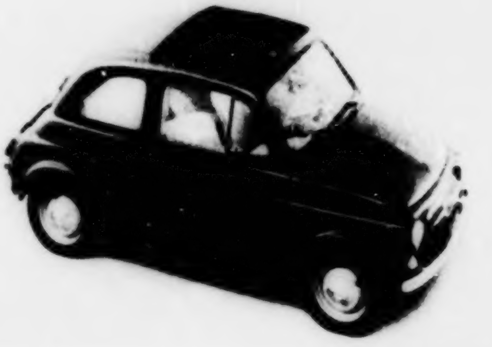


FIGURE 3

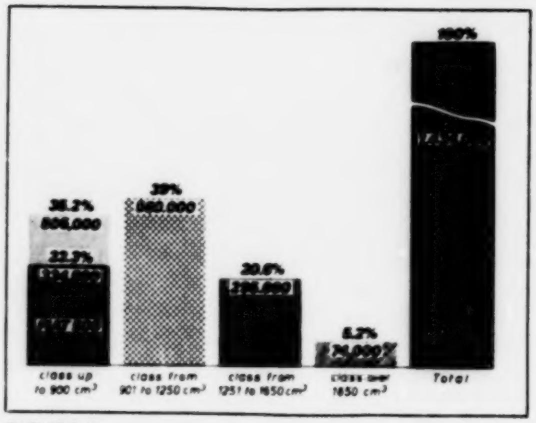


FIGURE 4

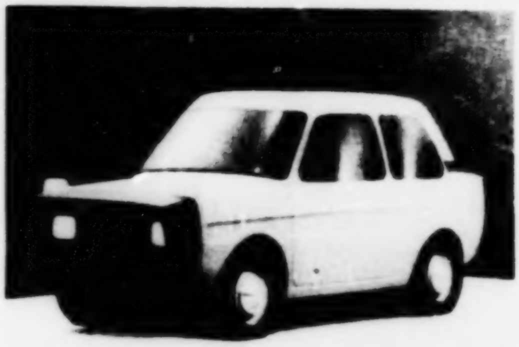


FIGURE 5

They become even more significant, if one thinks of the role that a car of similar characteristics might still have in the future, in those countries which are just beginning their social and industrial development.

In the light of these considerations, the great importance attached to the problems likely to affect the existence and future evolution of the small economy car, and the exhaustive studies and experiments which it was subjected to in the course of FIAT's car safety research program, appear more than justified.

As to the 700 kg E.S.V., the preliminary project studies started in October of 1971.

1) Preliminary studies	**:October 1971**
2) Project development	**:November 1971 – January 1972**
3) Construction of 2 prototypes	**:January – March 1972**
4) Prototype testing	**:April 1972 – December 1972**
5) Construction of 8 prototypes	**:May 1972 – November 1972**

During that month the general layout was defined and a choice was made of the line to be followed, in solving both high- and low-speed protection, and the aggressiveness problems.

Various form models of the car (Figure 5) were prepared simultaneously, based on a temporary structure diagram previously laid down by the Engineering Department.

At the end of the month it was possible to take a final decision on the Experimental Vehicle configuration.

In this connection, it should be pointed out that for this first series of prototypes, no real styling study was carried out, inasmuch as it did not fall within the basic scope of the research.

At the beginning of November 1971, the design work of the various bodywork groups was started; it was completed at the end of January 1972, thanks to the efforts of a large team of draftsmen in the Safety Research Department. The manufacture of the fixtures and first elements, however, had to be started at the beginning of the year in order to meet the end of March deadline for completing the two vehicle prototypes.

The main characteristics of the 700 kg E.S.V. (Figures 6, 7, and 8) are now illustrated.

Figure 9 shows the profile of this car superimposed on that of the 500 sedan.

The wheelbase of the car (Figure 10) is 1840 mm, the same as for the 500 model sedan; the maximum overall dimensions are

• length	3380 mm
• width	: 1450 mm
• height, fully laden	: 1340 mm

Front and rear overhang are 700 and 840 mm, respectively.

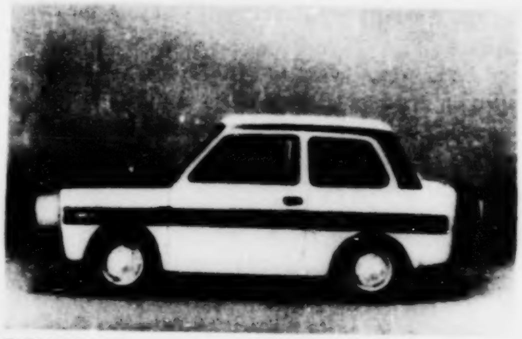


FIGURE 6

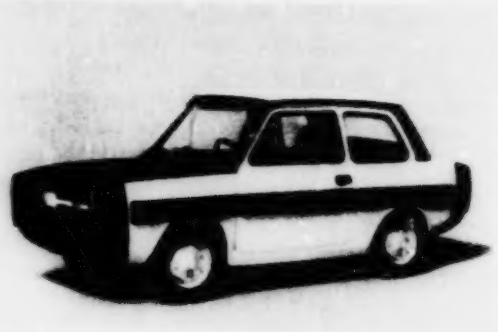


FIGURE 7

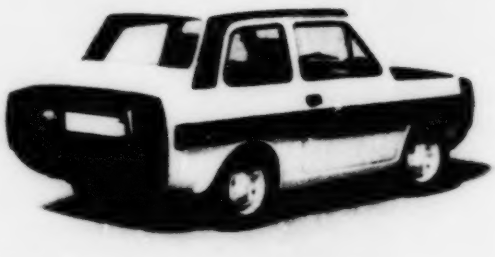


FIGURE 8

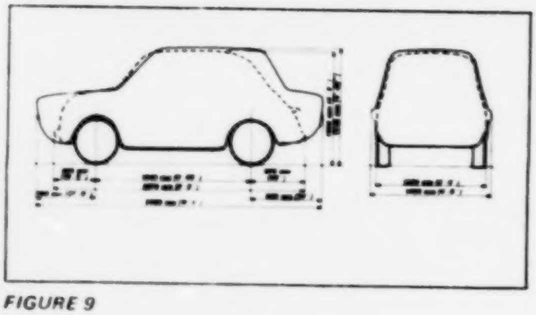


FIGURE 9

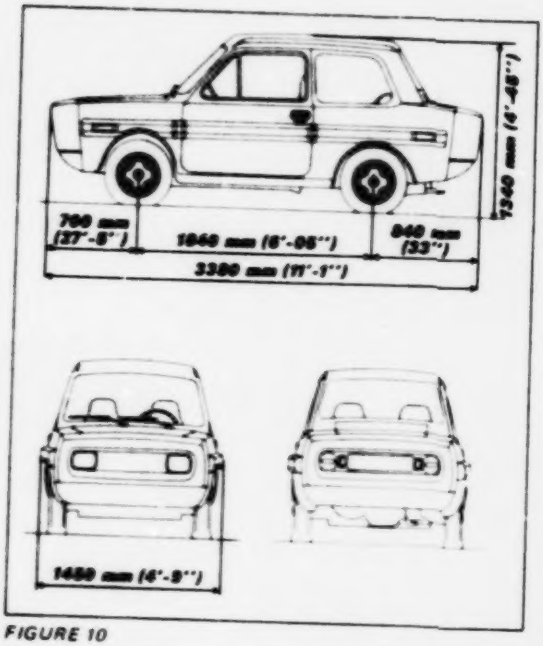


FIGURE 10

The car body end sections, of identical shape, consist of two easily removable deformable elements secured to the bodywork metal structure.

These elements, which will be described later on, in addition to providing protection at front and rear in low speed longitudinal and angled collisions, also reduce car aggressiveness particularly in the event of hitting pedestrians.

Protection of bodywork from damage which may be caused by slight side impacts (such as may occur, for example, when maneuvering in narrow spaces) is provided by deformable bands fitted to the sides at belt height.

This also diminishes aggressiveness.

The main front and rear lamp units are recessed in the two panels which longitudinally delimit the bodywork, and provide the bumper mounting plane.

The lamps are therefore in a well-protected position in collisions, since they are completely surrounded by the deformable elements, and are located 20 cm backwards with respect to the first-contact surface.

At the ends of the beltline protection bands, on the side panels, are arranged the turn signal lamp repeaters and the side marker lamps with reflex reflectors.

The side windows have fixed glass and adjustable ventipanes on the doors.

This solution was chosen, both to meet the requirement of preventing passenger ejection and to permit the fitting of an effective reinforcement structure between the door panels.

The passenger compartment interior (Figures 11, 12, and 13) does not have any particular features as regards passive protection elements and restraining systems for, as we pointed out earlier, the solution of these problems did not fall within the program concerning this first series of prototypes.

The mechanical components are now the same as for the standard FIAT 500 sedan (Figure 14).

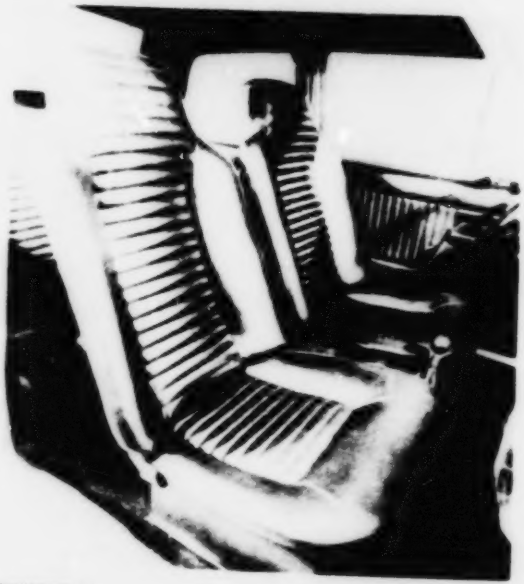


FIGURE 11

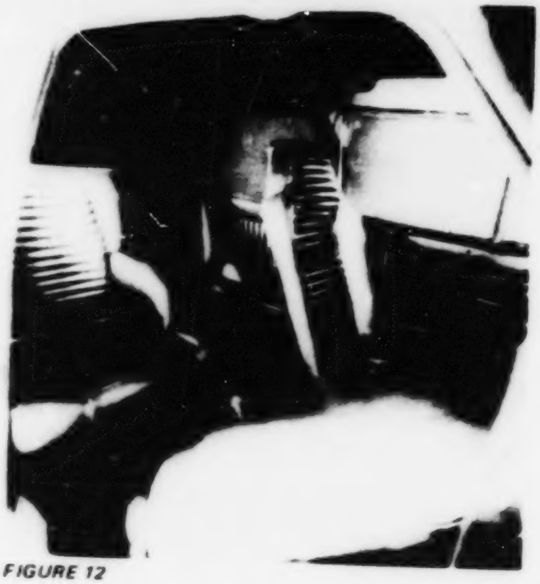


FIGURE 12

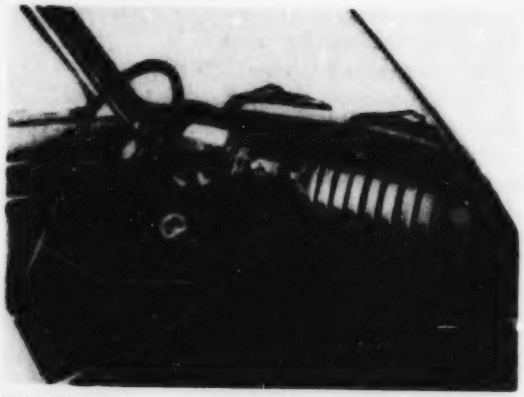


FIGURE 13

However, because of the new weight conditions, and to allow a first set of evaluation tests on behavior and performance on the road, larger size tires – 135-12 instead of 125-12 – and a more powerful engine with about 600 c.c. of displacement (derived from the original 500 c.c. engine) have been fitted.

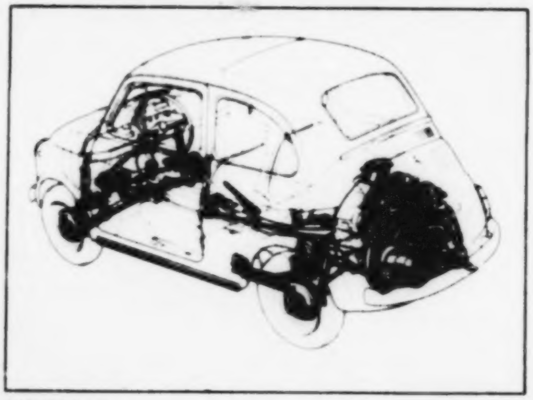


FIGURE 14

The study of the vehicle structure (Figure 15) represented the most exacting part of the design stage.

The limitations imposed by the use of existing mechanical components proved a source of great difficulty, as did the need to introduce substantial modifications in the provisional structures previously experimented on the 500 sedan.

All this without impairing, but rather improving efficiency.

The elements making up the bodyshell frame belong to three groups of structures, arranged at different heights.

The first group (Figure 16), at floor height, forms the main frame to which the suspension and propulsion components of the vehicle are anchored.

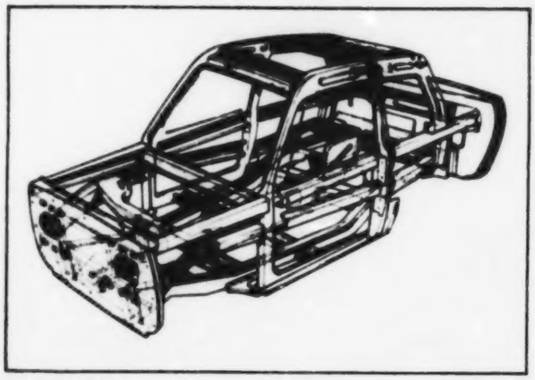


FIGURE 15

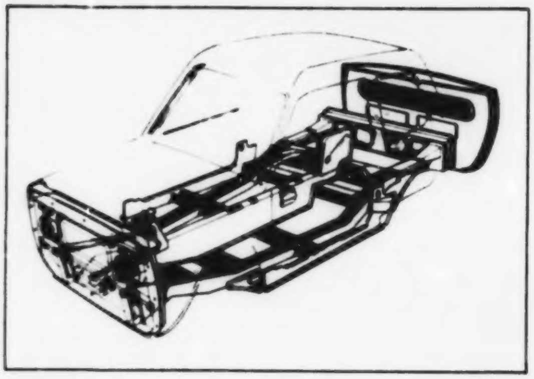


FIGURE 16

It consists of five longitudinal members, two of which run throughout the length of the body while one, central and with a sizeable cross-section, serves also as a tunnel for engine controls and as the heating systems duct.

These practically straight longitudinal beams are connected by five crossmembers in the section between the axles.

The second group of elements (Figure 17) at beltline height, consists of four longitudinal beams

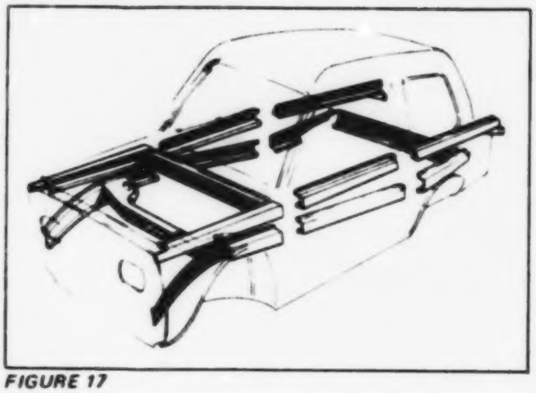


FIGURE 17

(two upper and two lower) arranged along the side and connected to each other by crossmembers.

The longitudinal beams, interrupted in the central portion by the door openings, are completed by stub beams fitted within the doors.

The third group of elements (Figure 18) is made up of three roof bows with their pillars and connection rails.

The first and second structure systems are interconnected at front and rear by two sturdy, shield-shaped cross elements designed to support the deformable body ends.

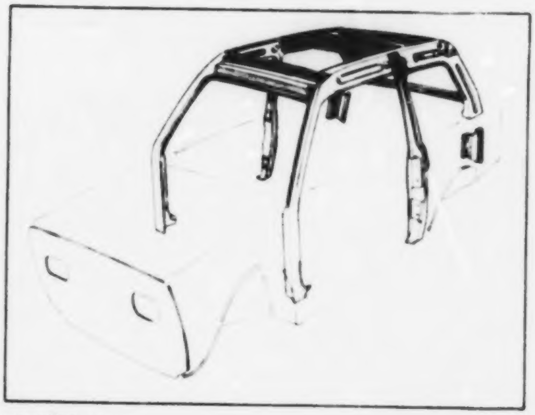


FIGURE 18

The rear shield is removable, to facilitate power plant installation and removal.

Figures 19, 20, and 21 show some assembly stages of prototypes, and complete the information on body constructional characteristics.

The self-regenerating bumper system developed for the E.S.V. was built in two versions.

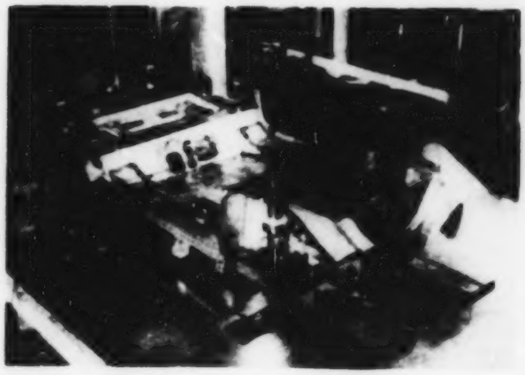


FIGURE 19

One version (Figure 22) of the pneumatic type, was studied in cooperation with PIRELLI, the manufacturers.

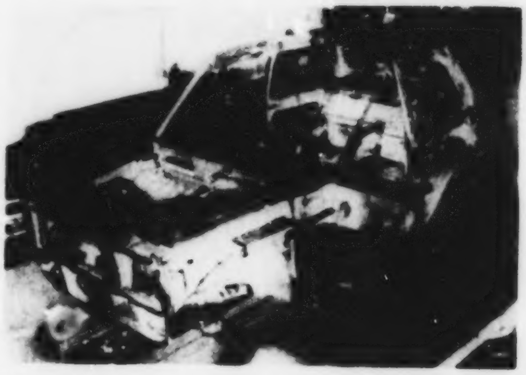


FIGURE 20

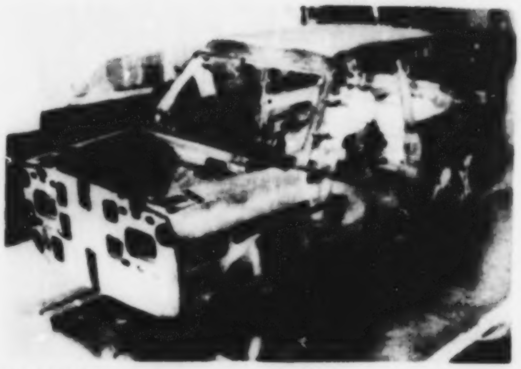


FIGURE 21

FIGURE 22

This version derives from previous experiments carried out on the SAPPER pneumatic bumper which was considered during the second International E.S.V. conference in Stuttgart.

Contrary to what was originally planned the discharge valves, whose opening occurred at a given vehicle deceleration, have been suppressed on the new bumper.

This measure both simplifies the system and makes it self-regenerating.

The bumper consists of a sheath of synthetic material, highly resistant to abrasion, containing two cylindrical bladders, one at the top and one at the bottom, interconnected by a rubber hose and inflated with air at very low pressure.

The inner volume not occupied by the bladders, is filled with elastically compressible synthetic foam.

Inflation of the two bladders takes place thorugh a single valve located centrally beneath the bumper.

A flat metal frame, forming the bumper supporting structure, is equipped with a set of screws for easy fixing to the body.

The second version, (Figure 23), studied jointly with STARS, a company of the FIAT Group, differs from the version described above only in that (the pneumatic portion having been eliminated), all the volume enclosed by the outer sheath is filled with synthetic foam endowed with particular elasticity and hysteresis characteristics.

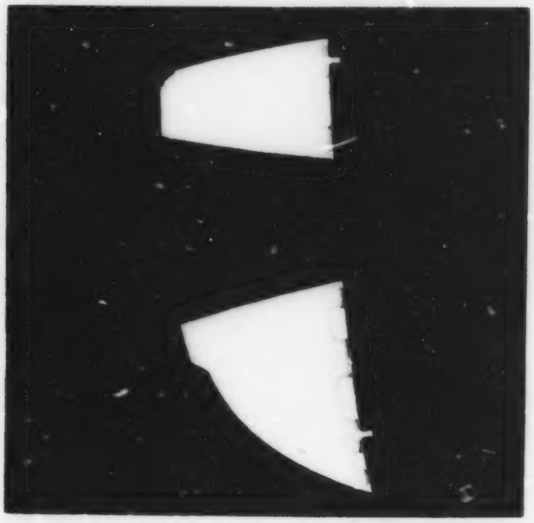


FIGURE 23

The charts in Figures 24, 25 and 26 were plotted during static compression tests carried out on the two types of bumpers with flat rigid plate and a 350 mm diameter pole.

The load-deformation and energy-deformation characteristics are given for different values of the inflation pressure for the PIRELLI bumper, and different density of the foam for the STARS bumper.

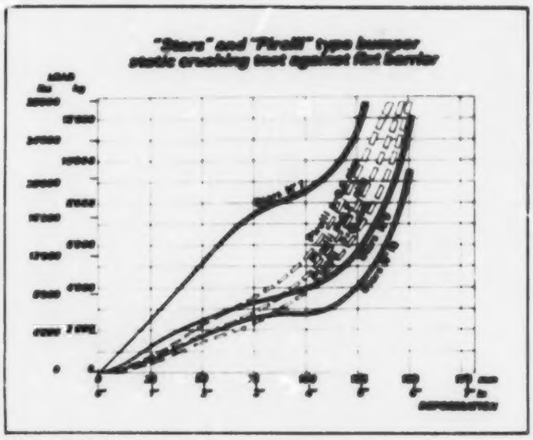


FIGURE 24

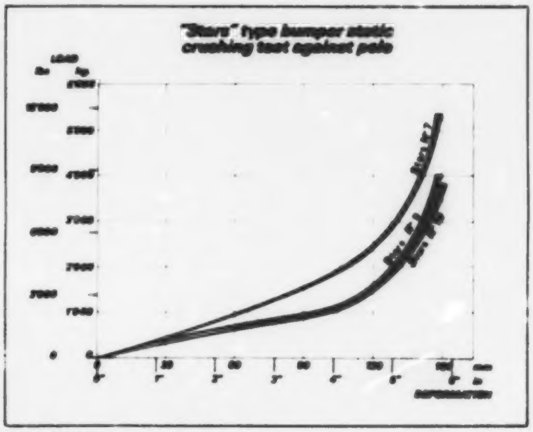


FIGURE 25

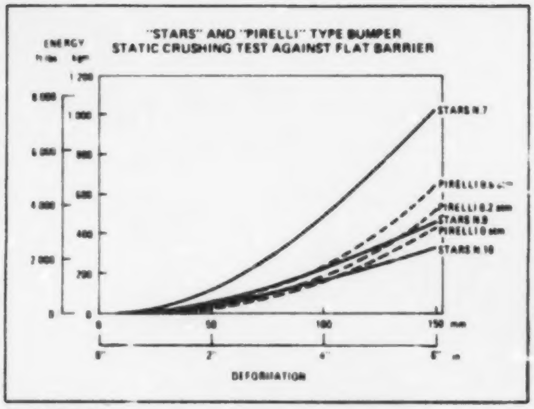


FIGURE 26

The maximum practical deformation for both types is approximately 15 cm, accounting for about 75% of bumper thickness.

In addition to the static tests, and before the final tests in the car, dynamic tests were run at progressively higher impact velocities, with the bumper assembly mounted on a dolly with mass and center of gravity identical to those of the car (Figure 17).

Also the behavior of the bumper when a pedestrian is hit was investigated by the same method.

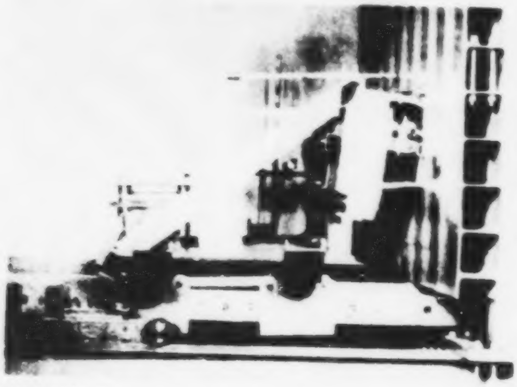


FIGURE 27

The results of the tests (Figures 28, 29, 30, 31, 32, 33, 34 and 35) run at the FIAT Safety Lab on one E.S.V. prototype, are given in Table I.

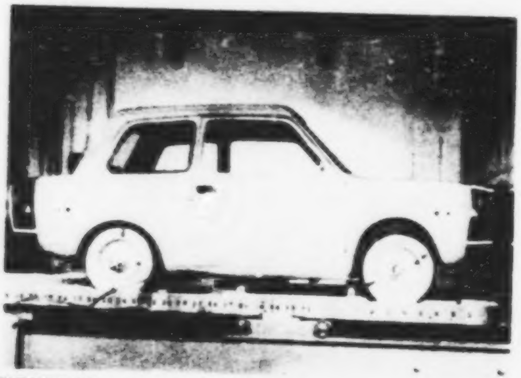


FIGURE 28

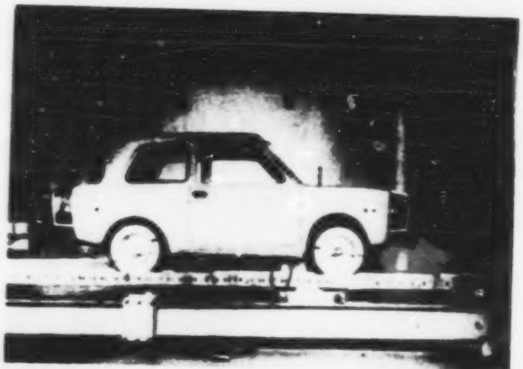


FIGURE 29

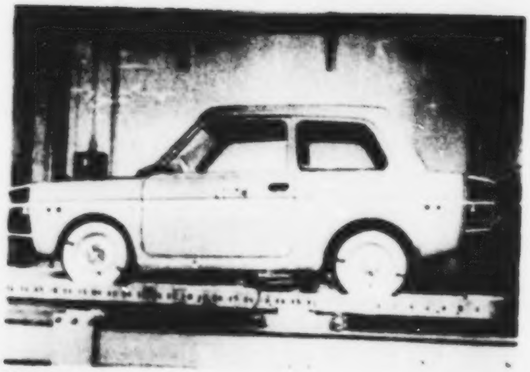


FIGURE 30

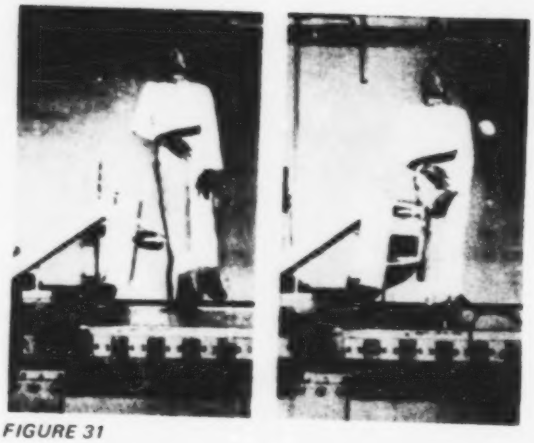


FIGURE 31

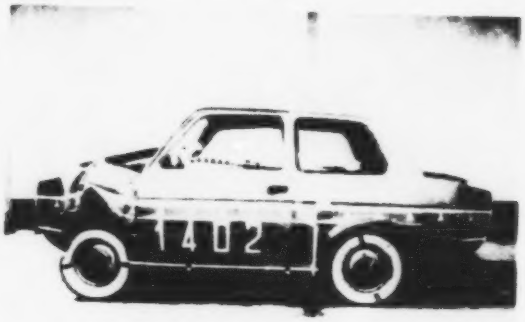


FIGURE 32

All the results of the various tests conducted meet the American E.S.V. specifications, except for the two slightly excessive values of intrusion at the footboard in the 50 mph front impact test, and at door centerline in the side impact test against a pole.

In consideration of the fact that the limitation of passenger compartment deceleration, does not appear

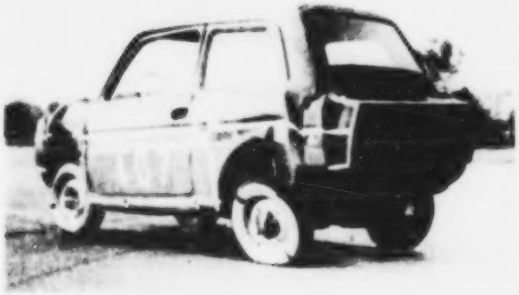


FIGURE 33

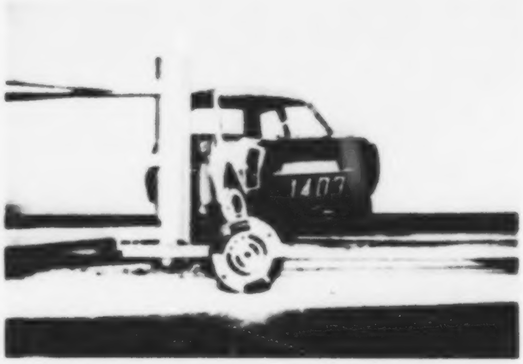


FIGURE 34

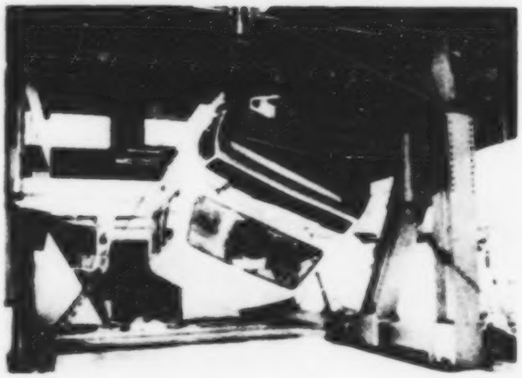


FIGURE 35

to be desirable, it should be noted that the positive results obtained in the field of "survival space" have in no way affected – as might have been feared – the possibility of solving the problem of occupants' survival, with any of the systems now under study.

The car deceleration charts (Figures 36 and 37) plotted during the longitudinal impact tests, show maximum values which are no cause for concern, i.e. about 68 g (against the 96 g measured on the reinforced 500 car) in the barrier test at 50 mph, and 14-15 g in the barrier test at 10 mph.

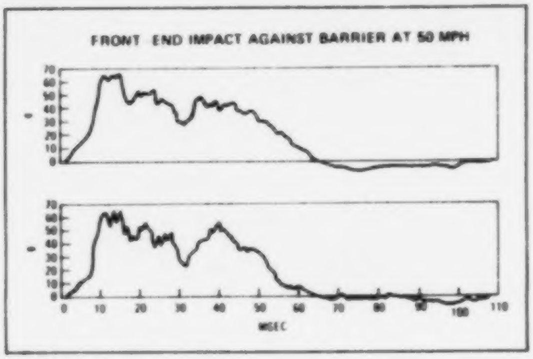


FIGURE 36

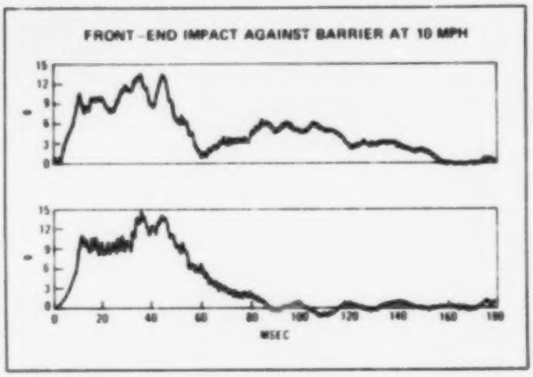


FIGURE 37

As done at the end of the second phase of research on the 500 sedan, a balance sheet should now be drawn up for these tests with the 700 kg E.S.V., by calculating, in terms of weight and sales price, the real cost of the "survival space," of the "low speed protection" and of the "reduction in aggressiveness" for the economical cars of the minimum weight class, and by comparing this cost with the forecasts we made about seven months ago at the second E.S.V. conference.

Table II comparing the most important technical and commercial data of the two cars (the 500 sedan and the 700 kg E.S.V.), gives a very significant picture of the severe consequences which could affect such class of vehicles, should manufactureres be compelled to meet the safety requirements covered in the investigation.

Weight increase in the order of 29% for the "survival space" alone and of 9% for low speed protection, with a consequent further increase, respectively, of at least 6% and 2% for the strengthen-

Collision Type	Speed		Test results
	MPH	KPH	
Impact against a barrier (Fig. 28)	10	16	No damage to car
Front impact against a pole (Fig. 29)	6	10	No damage to car
Rear impact against a barrier (Fig. 30)	10	16	No damage to car
Impact against a pedestrian (Fig. 31)	10	16	Load measured in the two areas, upper and lower, of contact: 420 and 230 kg (against the 820 kg found in the test with standard metal bumper)
Front impact against a barrier (Fig. 32)	50	80	Steering wheel rearward displacement: 4 cm; maximum intrusion into passenger compartment: 3 cm at the instrument panel, 10 cm at the footboard; fuel tank unharmed.
Rear impact (Fig. 33)	50	80	Max. intrusion into passenger compartment: 5 cm
Side impact against a pole (Fig. 34)	15	25	Max. intrusion into passenger compartment: 12.5 cm (at door centerline)
Simulated rollover with oblique fall from a height of 60 cm.			Max. intrusion into passenger compartment: 6.2 cm. It should be noted that this value is rather disappointing since the roof fall test was the last to be run and therefore the car was not fully undamaged

TABLE I

ing of mechanical components, are all reasons for deep concern (Table III).

Overall dimensions:		Model 500	E.S.V. 700	
			Expected	Current
Length	mm	2,970	3,250	3,380
Width	mm	1,320	1,440	1,450
Height	mm	1,292	1,340	1,340
Weights:				
Curb weight	kg	520	670	760
Fully laden	kg	840	990	1,080
Cost:				
Sales price for Italy	L.	600,000	780,000	840,000

Only applying to "survival space"
"Survival space"
"low-speed protection"
"reduction of aggressiveness"

TABLE II

These percentages would involve a price increase of 240,000 lire, equivalent to an increase of 40% over the original price, which cannot but give rise to dougts and perplexities about the actual boundaries within which the problems of vehicle safety can be tackled.

The importance to be assigned to the cost benefit ratio was pointed out earlier: it is time that the maximum acceptable value of the above ratio can be questioned, but we feel it is legitimate to ask that it always be the result of an operation in which benefit can be expressed by a positive number.

	Survival space	Low speed protection and reduction of aggressiveness	Total
Dimensions:			
Length	+ 4%	+14%	+18%
Width	+ 4%	+ 6%	+10%
Height	+ 4%	+ 0%	+ 4%
Overall dimension	+ 8%	+17%	+25%
Weight:	+29% +35% + 6%	+ 9% +11% + 2%	+46%
Cost:	→		+40%

TABLE III

This would not be true if a class of cars of significant social value had to be sacrificed in the name of safety.

A solution of this kind would not meet with our approval, and this is the reason why we shall leave no stone unturned in order to reach the most advanced goals of Safety by reasonable means.

FINAL COMMENTS MADE AFTER THE FIAT TECHNICAL PRESENTATION

DR. ING. OSCAR MONTABONE

In addition to what said during the presentation made yesterday by the French Delegation I wish to say a few words of comment to the FIAT technical presentation.

For the U.S.A. it may appear strange that in carrying on its E.S.V. program FIAT gave priority to the study of the small, 1500-lb. car and, probably, what said in our reports was not sufficient to clearly evidence the reasons behind our work. Therefore, I wish to add the following:

a) Since a complex problem must be tackled, it is advisable to investigate as quickly as possible the limit conditions of the same (maximum weight and minimum weight), since the "maximum weight" class was considered in this country, we have chosen the other extreme.

b) Europe differs significantly from the U.S.A. in its geographic configuration, road network, and living standards so that, in many areas, the small, economical car is a necessity.

c) In Europe – and here I am repeating things which though already said, are of fundamental importance – the "first-car" problem for those who on account of their income cannot afford to invest too much money in a car, will still exist for many years. It therefore becomes necessary to know how much more this category of motorists will have to disburse for the safety car.

The conclusions we presented confirm, or rather make more pessimistic, the Stuttgart forecasts, viz. that with the present state-of-the-art of engineering and technology, the FIAT engineers think that by continuing on the lines of the U.S.A. – E.S.V. specifications it will not be possible in future to meet the motorization requirements of a remarkable fraction of the European population.

The French Delegation presentation has also stressed the importance of another serious problem already in act today – which the E.S.V. program will render extremely severe and of very difficult solution.

Europe has, and will continue to have in the next years, a population of cars widely diversified in weight and size. It ensues that if valid solutions are wanted, also the problem of the coexistence on the same road of different cars shall be solved.

We hope we can bring in Tokyo a contribution to the solution, or better to the exact definition of the problem, by supplying the first results on the behavior of our three experimental safety cars of 1500, 2000 and 2500 lbs., respectively.

Today we think however that two fundamental recommendations can be proposed.

1. We know the number of the persons who die on the roads but, unfortunately, we do not know equally well how they die. Therefore, more statistical data are necessary. But these data must be submitted through an identical information processing method, i.e. by adopting the same data recording and processing system in all countries. In our opinion, this action – to be effective – should be undertaken prevailingly by the State Administrations, and in particular, it should be piloted by the CCMS Committee established within NATO. It should be stressed, however, that so far, after about two years, not many data have been collected by this Committee.

   Why not foster this investigation at the cost of reviewing the scheme adopted so far in order to render it more flexible and more apt to yield statistical data of more general validity?

2. An overall solution – assuming that such a solution exists – for all the problems singled out during these E.S.V. conferences, and for those which will stem out in the next months, will involve a tremendous percentage increase in car costs, more so for the small cars, and, consequently – provided that formulas are found to help those with a lower income to buy a car – an enormous annual expense for the community.

   Is it not proper, then, to ask whether a less expensive solution of the problem exists and whether the solution we are studying is the right and only one?

   In other words, why not look for a different solution which links the two terms of the problem: the car and the road?

   We know that front collisions in general, and between two cars in particular, side impact and rollover are the major causes of deaths inside the cars. Why not, then, prevent front end collisions and rollovers through a new road organization (one-way roads with guardrail, without crossings)?

In conclusion, safer cars than those of today, but at a more acceptable cost, with a better general cost/benefit ratio for the community. On the other hand this is not a new idea and it was Secretary Volpe who said that total safety is represented by a triangle whose vertices are: road-man-car.

THE GERMAN TECHNICAL PRESENTATION

SECTION 2 PART 5

FEDERAL REPUBLIC OF GERMANY

MR. HELMUT WAGNER, *Deputy Assistant Secretary*

Federal Ministry of Transportation

INTRODUCTION

Good afternoon ladies and gentlemen. It is my honor to introduce the technical presentations of the Federal Republic of Germany. The first presentation will be made by Dr. Scherenberg of the Daimler-Benz Company who will discuss ESV development work. Next, Dr. Brumm of the Adam Opel Company will present their ESV status. The Volkswagen presentation will be given by Professor Fiala, and, lastly, two papers by Dr. Danner and Dr. Langwieder on accident research conducted by the German motor insurers. Dr. Scherenberg . . .

DR. HANS SCHERENBERG, ***Board Member***

Daimler-Benz

Mr Chairman, Ladies and Gentlemen:

We at Daimler-Benz are pleased to meet with you all once again for a continuation of the important international technical discussions on experimental safety vehicles.

My report to you this afternoon will cover three main topics:

1. A review of the test results of the Daimler-Benz ESV 05 which was displayed during the 2nd International Technical Conference on Experimental Safety Vehicles last October in Sindelfingen. These results remain the basis of our continued efforts in the ESV field.
2. An explanation of the current status of our ESV development work including a description of the Daimler-Benz ESV 13, now on display at Transpo 72.
3. A discussion of some of the basic thinking and concepts within our company of the ESV program specifications developed by the U.S. Department of Transportation and the Ministry of Transport of the Federal Republic of Germany. We have had meaningful negotiations on these subjects in some areas with appropriate agencies of the German government and would like to share these thoughts with all the other government and industry participants at this important conference.

DBAG ESV 05 RESULTS

In February 1971, two months after the signing of the Memorandum of Understanding between Secretary Volpe and Minister Leber, Daimler-Benz began the development of its own experimental safety vehicle. We selected a Mercedes-Benz Model 250 as the reasonable base for this vehicle since our production vehicles already have incorporated many safety features which were developed from our basic production and research development technical data. A part of our normal extensive engineering and development activities for series production we naturally shifted to more concentration on the requirements of the ESV specifications in the area of active as well as passive safety. By the summer of 1971 the first prototypes were completed and in October 1971 the Daimler-Benz ESV 05 was operational.

At the specific request and suggestion of the Minister of Transport of the Federal Republic of Germany, Mr. Leber, this vehicle was shown to Secretary Volpe and also to all the participants at the Sindelfingen conference. This action was taken in accordance with the Memorandum of Understanding between the German and U.S. governments.

The ESV 05 met all German and most of the U.S. specifications as far as active safety is concerned. Some of the characteristics, for instance viewing angles, did not entirely meet the U.S. specifications. However, we believe that in the case of viewing angles the specifications are not necessary to obtain satisfactory visibility and, in addition, are very difficult to achieve in small and medium sized cars.

We also considered equipping the ESV 05 with a periscopic mirror, in order to improve indirect visibility, but after critical evaluation have decided against it. We found that technically it would be extremely difficult to arrive at a satisfactory design and, on the other hand, the possibilities to adopt and utilize such equipment are very limited. In addition, the periscope creates some dangers as far as the interior safety is concerned. We are of the firm belief that good, conventional mirrors in unison with a well designed body provide an excellent view of the rear of vehicles. Occupant crash protection tests of the ESV 05 were conducted in some preliminary frontal impacts with the total vehicle against a solid barrier.

Even though not fully satisfactory, this test, in the summer of 1971, has shown gratifying results when compared to the very high ESV requirements. Almost

100% passenger protection was attained when using both seat belts and air bags. We continue to use both restraint systems together, seat belts and air bags, since at this time neither of the two systems alone is far enough developed for adequate occupant crash protection according to the ESV specifications. We also have experienced added results in using both systems within the present state of the art. Our test has confirmed this and I will discuss later the basic questions of proper selection of well suited restraint systems.

The crash test of the ESV 05 produced the following results. In each of the five injury criteria — permissible load on the head, chest, pelvis, and both femurs — the driver met three, the front seat passenger all five, the left rear passenger also three, the right rear passenger also all five. As indicated in my presentation during the 2nd ESV Conference the data for the most critical seating location, the front seat passenger, is as follows.

Head of the dummy 64g (with a suggested limit of 80g)
Chest 36g (with a suggested limit of 60g)
Pelvis 54g (with a suggested limit of 60g)
Left femur 520kg (with a suggested limit of 550 kg)
Right femur 440kg (with a suggested limit of 550kg)

It is fair to assume that even higher injury criteria would have been met if we would have had dummies available which do not have the deficiencies and limiting conditions known for so long and therefore are incapable of producing precise occupant crash protection data.

After showing you again our concept and some technical data of our ESV 05 I would like to now report to you on our continued effort which we have employed since October 1971.

DBAG ESV 13

This vehicle constitutes a progressive development of the ESV 05 and includes all safety features of the ESV 05 but is stylistically more acceptable. The design basis in this instance was also the Mercedes-Benz 250 and components of the 350SL. The wheel base has been extended 100 mm to 2850 mm as was the ESV 05. This was done to satisfy a questionable angle of visibility specification of the U.S. program, to create space for the modified driver's seat and the restraint system for the protection for rear seat passengers. The overall length is now 5235 mm against 4685 mm of the production car.

This increase in length was necessary in order to provide room for the regenerative buffers and rein-

forced front and rear body structure and also to provide controlled deceleration of the passenger compartment during high speed impacts.

Nevertheless, ESV 13 is 145 mm shorter than its predecessor since, in the meantime, improved bumper arrangements have been developed. Measures to increase occupant protection for side impact increased the overall vehicle width to 1796 mm in contrast to a production vehicle of 1770 mm. The height of the unloaded vehicle is 1430 mm, and the curb weight approximately 2100 kg.

With regard to active safety we rely entirely on the well proven components of the ESV 05, which already in October 1971 offered a maximum of handling and driving stability, utilizing a modified MB 250 chassis. Also the environmental, operational and visibility safety represented the state of the art of Daimler-Benz safety research.

To provide for the protection of pedestrians, we have applied exterior padding to the front, as well as the rear panels, the side of the bumpers as well as possible contact areas on fenders and body corners. Also from the ESV 13 we can expect the same structural integrity, i.e. energy absorbing capability, as with the ESV 05.

Safety belts are used again for all occupant positions, in addition to air bags in the steering wheel hub, in the dashboard and in the front seat back rest for the protection of rear seat passengers. We would like to call your attention specifically to our passive belt system for the front seats, which in many demonstrations, especially in the past few days at the ESV stand at Transpo, has found wide acceptance from the public and knowledgeable individuals in the field of occupant restraint.

May I now show you without discussing details to what extent our ESV and production vehicles meet the specifications. The first column shows specifications which are already met in series production. The third column shows those features required by the specifications which are still under development. The fourth column shows specifications which are not satisfied by ESV 13. These charts show already, even when skimmed over quickly, that our production models do satisfy most of the ESV specifications and that the ESV 13 is lacking in only a very few points.

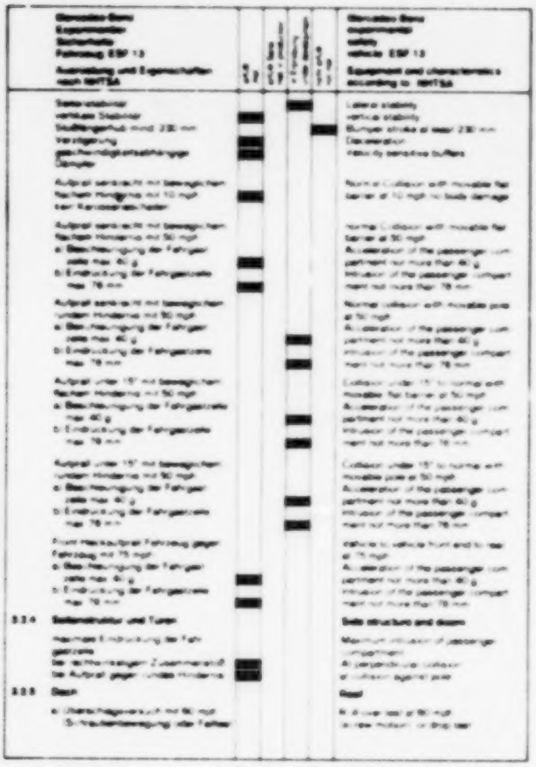
In the column "Not Met," four are angle of visibility specifications. Also we do not meet the vehicle weight specifications and, because of this, the desired acceleration due to the fact that the V-6 engine of the ESV 13 could not in the available time be optimized.

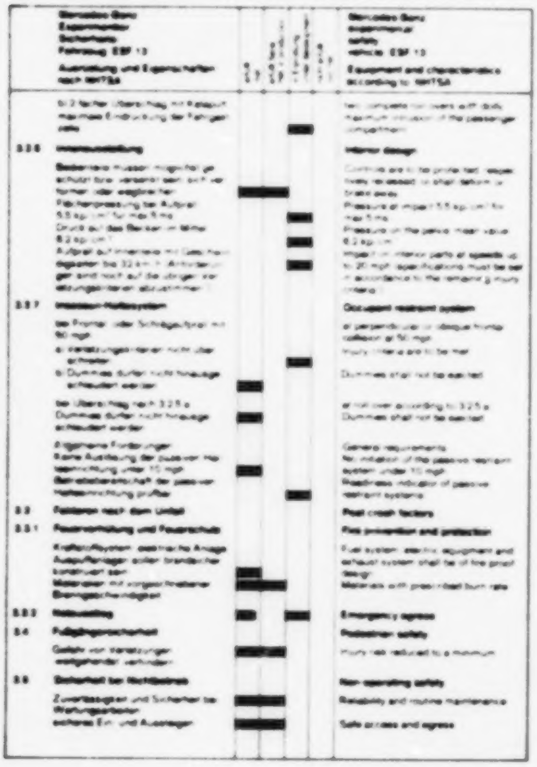
	Mercedes Benz Experimentier Sicherheits Fahrzeug ESF 13	Mercedes Benz experimental safety vehicle ESF 13
	Ausrüstung und Eigenschaften nach NHTSA	**Equipment and characteristics according to NHTSA**
1	**Einführung**	**Introduction**
2	**Projektumfang**	**Project scope**
2.1	**Forderung hinsichtlich Gestaltung**	**Design requirements**
	4-türige Limousine	Four door sedan
	5 Sitzplätze	five seating positions
	Leergewicht 1815 ± 80 kg	Curb weight 1815 ± 80 kg
	Nutzlast 454 kg	vehicle capacity weight 454 kg
	Radstand max. 3,15 m	Wheel base not more than 3,15 m
	Spur vorn und hinten max. 1,65 m	Front and rear treadwidth not more than 1,65 m
	Breite max. 2,15 m	Overall width not more than 2,15 m
	Höhe max. 1,47 m	Overall curb height not more than 1,47 m
	Länge max. 5,59 m	Overall curb length not more than 5,59 m
	relative Länge Radstand max. 1,9	Ratio of overall curb length to wheel base not more than 1,9
3	**Leistungsspezifikation**	**Performance specification**
	Zuverlässigkeit und geringe Wartung	Reliability and low maintenance
	Auslegung der Sitzplätze für 5% Frau bis 95% Mann	Arrangement of seats to accommodate 5 perc. female up to 95 perc. male
3.1	**Maßnahmen zur Vermeidung von Unfällen**	**Accident avoidance**
3.1.1	**Bremswirkung**	**Braking performance**
	Betriebsbremsanlage	Service brake
	Bremsweg	Stopping distance
	Fading Test	Fading test
	Gütegrad	efficiency rating
	Feststellbremse	parking brake
	Notbremse	Emergency brake
	Funktionsfähigkeit bei Ausfall eines Teiles	Capability to function in case of partial failure
	bei Ausfall eines Bremskreises	to failure of one braking circuit
	a) vorn	front circuit failure
	b) hinten	rear circuit failure
	bei Ausfall der Hilfskraft	to failure of booster
3.1.2	**Lenkung**	**Steering**
	Gierreaktion	Yaw response
	Kurvenradiusverlauf in definiertem Bereich nach Loslassen der Lenkung	Yaw rate within the defined envelope after steering wheel release
	Verlauf Giergeschwindigkeit zu Lenkwinkel in definiertem Bereich bei Anreißen der Lenkung	Ratio of Yaw velocity to front wheel angle within defined envelope after a quick steering input

	Mercedes Benz Experimentier Sicherheits Fahrzeug ESF 13	Mercedes Benz experimental safety vehicle ESF 13
	Ausrüstung und Eigenschaften nach NHTSA	**Equipment and characteristics according to NHTSA**
	Sicht nach hinten	**Rear visibility**
	Innenrückspiegel	Inside rearview mirror
	horizontaler Blickwinkel mind. 24°	horizontal view angle at least 24°
	vertikaler Blickwinkel mind. 8°	vertical view angle at least 8°
	Einsicht zur Fahrbahn bei mind. 15 m	Road surface shall be visible at least 15 feet behind
	Reflexionsgrad	Reflectance value
	Umstelleinrichtung für Nachtfahrt	night driving selector
	Außenrückspiegel	Outside rearview mirror
	horizontaler Blickwinkel mind. 17°	horizontal view angle at least 17°
	Einsicht zur Fahrbahn bei mind. 10,7 m hinter Außenrückspiegel	Road surface shall be visible at least 10,7 m behind outside rearview mirror
	vom Fahrersitz aus einstellbar	adjustable from the driver's seating position
	keine Unterbrechung der Fahrersichtlinien bis 17° im Hochwinkel	no obstruction of the driver's line of sight below the the 17° up angle
3.1.6	**Anzeige- und Kontrolleinrichtungen**	**Displays and controls**
	Instrumente leicht ablesbar	Instruments easy to read
	Vermeidung von Spiegelungen	Non reflecting covering glasses
	von Hand betätigte Bedienteile	Manual controls
	leicht erreichbar	easy to reach
	unverwechselbar angeordnet	located to prevent unintentional actuation
	durch Symbole gekennzeichnet	identified by symbols
	fußbetätigte Bedienteile	foot controls
	mit jedem Schuhwerk zu betätigen	suitable for all footgear
	Gaspedal abgeschirmt	guarded acceleration control
	Anpassung an 5% Frau und 95% Mann	Adaption to 5 percentile female and 95 percentile male
3.1.7	**Antriebsmaschine**	**Engine**
	Emissionswerte	emission characteristics
	Reichweite	Action radius
	Beschleunigung	Acceleration
	bei Querbeschleunigung keine Motoraussetzer	no drop of engine output at lateral acceleration
3.1.8	**Fahrkomfort**	**Riding comfort**
	Eigenfrequenz	Natural ride frequency
3.2	**Verminderung von Unfallverletzungen**	**Crash injury reduction**
3.2.1	**Fahrzeugstruktur**	**Vehicle structure**
	Bremskräfte	Braking
	Seitenkräfte	Cornering
	Auffahren auf Bordstein	Curbing
	Einfedern	Bounce
	Ausfedern	Rebound
	ausreichende Steifigkeit	sufficient stiffness

	Mercedes Benz Experimentier Sicherheits Fahrzeug ESF 13	Mercedes Benz experimental safety vehicle ESF 13
	Ausrüstung und Eigenschaften nach NHTSA	**Equipment and characteristics according to NHTSA**
3.1.3	**Fahrverhalten**	**Handling**
	Querbeschleunigung	Lateral acceleration
	Seitenwindempfindlichkeit	Crosswind sensitivity
	Ausbrechmoment bei Gaswegnahme	Control at breakaway
	Rückstellmoment am Lenkrad	Steering control sensitivity
	Verhalten bei Ausfall der Hilfskraft	Characteristics at failure of power assistance
3.1.4	**Überschlagsicherheit**	**Overturning immunity**
	Kein Kippen bei 180° Lenkeinschlag	Overturning immunity at the steering wheel deflection value of 180°
	Kein Kippen bei Slalom	Overturning immunity at pylon course
3.1.5	**Sicht**	**Visibility**
	Scheinwerfer	**Headlamps**
	Lichtstärke	light intensity
	Leuchtweitenregelung	headlight vertical aim control
	Rückwärtige Beleuchtungsanlage	**Rear lights and signals**
	Trennung von Bremslicht, Blinker, Schlußlicht: mindestens zwei getrennte Leuchten	Separation of stop lights, turn signal, tail lights (at least two separate lamps)
	Bremsleuchten bei eingeschalteter Zündung	Stoplamps switched on together with ignition
	Kontrolleinrichtung für Schlußleuchten	Lamp failure indicator
	Scheibenwischer für Frontscheibe	**Windshield wiper**
	2 Frequenzen	2 frequencies
	Scheibenwascher für Windschutzscheibe	**Windshield washer**
	SAE J 942	SAE J 942
	Heckscheibe	**Rear window**
	Scheibenwischer	Wiper
	Entfrostung und Entfeuchtung elektrisch beheizte Heckscheibe	Defrosting and defogging electrically heated rear window
	Blendung durch reflektierende Teile	**Glare from reflecting surfaces**
	MVSS 107	MVSS 107
	Sicht nach vorn und nach den Seiten	**Forward and side visibility**
	horizontal je 135°	horizontal 135° on either side
	vertikal 17° nach oben	vertical 17° up
	8° nach unten	8° down
	max. 4 Säulen im vorgeschriebenen Sichtbereich	not more than 4 pillars in the required visibility area

	Mercedes Benz Experimentier Sicherheits Fahrzeug ESF 13	Mercedes Benz experimental safety vehicle ESF 13
	Ausrüstung und Eigenschaften nach NHTSA	**Equipment and characteristics according to NHTSA**
3.2.2	**Vorderes Stoßfängersystem und Vorbaustruktur**	**Front bumper system and vehicle structure subsystem**
	Mittellinie des Stoßfängers bei 431,8 ± 25,4 mm von der Fahrbahn	Horizontal center line of bumpers 431,8 ± 25,4 mm above road surface
	Schutz gegen Unter- und Überfahren	Protection against underride and override
	Seitenstabilität des Stoßfängers	Lateral stability
	vertikale Stabilität	vertical stability
	Stoßfängerhub mind. 230 mm	bumper stroke at least 230 mm
	Verzögerung	Deceleration
	geschwindigkeitsabhängige Dämpfer	velocity sensitive buffers
	Aufprall senkrecht auf starres flaches Hindernis mit 10 mph: kein Karosserieschaden	Normal collision against fixed flat barrier at 10 mph: no body damage
	Aufprall senkrecht auf starres flaches Hindernis mit 50 mph	Normal collision against fixed flat barrier at 50 mph
	a) Beschleunigung der Fahrgastzelle max. 40 g	Acceleration of the passenger compartment not more than 40 g
	b) Eindrückung der Fahrgastzelle max. 76 mm	Intrusion of the passenger compartment not more than 76 mm
	Aufprall senkrecht auf starres rundes Hindernis mit 50 mph	Normal collision against fixed pole at 50 mph
	a) Beschleunigung der Fahrgastzelle max. 40 g	Acceleration of the passenger compartment not more than 40 g
	b) Eindrückung der Fahrgastzelle max. 76 mm	Intrusion of the passenger compartment not more than 76 mm
	Aufprall unter 15° auf starres flaches Hindernis mit 50 mph	Collision under 15° to normal against fixed flat barrier at 50 mph
	a) Beschleunigung der Fahrgastzelle max. 40 g	Acceleration of the passenger compartment not more than 40 g
	b) Eindrückung der Fahrgastzelle max. 76 mm	Intrusion of the passenger compartment not more than 76 mm
	Aufprall unter 15° auf starres rundes Hindernis mit 50 mph	Collision under 15° to normal against fixed pole at 50 mph
	a) Beschleunigung der Fahrgastzelle max. 40 g	Acceleration of the passenger compartment not more than 40 g
	b) Eindrückung der Fahrgastzelle max. 76 mm	Intrusion of the passenger compartment not more than 76 mm
	Front-Aufprall Fahrzeug gegen Fahrzeug mit 75 mph	Head on collision vehicle to vehicle at 75 mph
	a) Beschleunigung der Fahrgastzelle max. 40 g	Acceleration of the passenger compartment not more than 40 g
	b) Eindrückung der Fahrgastzelle max. 76 mm	Intrusion of the passenger compartment not more than 76 mm
3.2.3	**Hinteres Stoßfängersystem und Heckstruktur**	**Rear bumper system and rear structure subsystem**
	Mittellinie des Stoßfängers bei 432,5 ± 25,4 mm von der Fahrbahn	Horizontal center line of the bumper at 432,5 ± 25,4 mm above road surface
	Schutz gegen Unter- und Überfahren	Protection against under- and override





While the goals of the ESV specifications have been met in general by ESV 05 and 13, our current phase of development shows how far away the experimental safety vehicle is from an economically acceptable vehicle concept. Our ESV 13 is 550 mm longer and almost 700 kg heavier than the comparable production vehicle from which it is derived. Increased cost and increased price for such a vehicle is not debatable since here in essence we are talking only about an ESV with only upper limit specifications. Considering only the dimensions, weight and very expensive optional equipment it must be recognized, that even if mass production would be possible, the price would have to be so high that the vehicle could not be marketed.

Needless to say, the cost/benefit ratio would be far from acceptable. The purpose of such a vehicle is recognized as an experimental object which may at the right time produce valuable data for the development of future production vehicles.

ESV PROGRAM CHANGE SUGGESTIONS

It is well known to all participants, that there is a wide gap between the safety standards now in effect and the ESV specifications, which in the future will be narrowed as new standards are issued. To derive timely new information in this area, the gap should, in our opinion, be narrowed in logical increments or steps. In the sense of such an incremental plan, we first define the goal of our ESV development to meet the injury criteria in a frontal impact at 40 mph. This impact speed is on the upper range of the statistically significant accident speed range as found in Germany. We feel that it would be a significant step forward within the framework of the ESV project to evaluate impact conditions at this speed.

Compared to the legally required 30 mph test speed in the U.S. standards, an impact energy of 1.8 times greater results at a speed of 40 mph when the vehicle weight remains the same. Since the vehicle must logically become heavier, the energy to be absorbed will then more than double.

In addition, it is necessary not only to limit the steering rearward displacement at 30 mph as presently required, but now to also remain below the injury criteria level at 40 mph. In our opinion the proposed objectives of the ESV research task were set too high initially, particularly in view of the cost/benefit question, and should therefore be re-evaluated in view of what we all have learned as a result of these three international conferences.

As a prerequisite to satisfy not only ESV specifications but also future scheduled standards, the development of feasible restraint systems is urgently necessary. In the area of air bags, we have been working diligently for many years in cooperation with American as well as German systems manufacturers. Progress has been made in the area of sensor development and in respect to dimensions of solid gas generators.

There remain, however, several basic unanswered questions concerning the functional principle of air bag systems. In this context there is also the question as to the tolerable degree of gas toxicity and heat generation and the extent to which present values should be reduced.

We are intensively involved in further developing single hand operated safety belt systems, and also passive belt systems. Extensive sled tests show, that the injury criteria for the chest, pelvis, and femur can be met at least for equivalent barrier impact speeds up to 40 mph by means of safety belts with belt force limiters, while with respect to the head, difficulties arise even at about 30 mph. These difficulties are caused by the rotational velocity with which the driver's head is moving at the end of the deceleration phase and by the high deceleration of rotation itself which occurs as soon as the chin contacts the chest. At this point the vertical component exceeds considerably the a.p. (anterior-posterior) component. This leads to the question, whether it is realistic to apply to the vertical component the same severity index, which has been developed primarily for the a.p. direction. In our opinion we feel that a reduced yardstick in the ratio of 1:1.5 should be employed in the vertical direction, or that at least temporarily only the a.p. component should be considered in evaluation of injury risk. In any case this problem should be subject to detailed medical tolerance studies.

Realizing that head rotation and head deceleration have decisive influences on the evaluation of survivability, we must recognize that the most delicate part of available dummies is in the neck design. Frequent repairs and adjustments reduce even further the reproducibility factor from dummy to dummy, from manufacturer to manufacturer, from test to test which even now is not satisfactorily assured.

The previously mentioned head rotation may be reduced in three ways:

1. By an as far as possible pendular motion of the upper torso almost to a horizontal position. In today's vehicles this space is unavailable and the space will be even less available in a safety vehicle whose interior space has been lessened by additional padding because the overall length has *not* been extended for this particular purpose.
2. By ride-down of the upper torso as soon as possible during the initial phase of deceleration using an as uniform as possible high restraint force. This can be achieved with pre-loading devices which at the time of impact take up slack and produce a pre-loading force transmitted from the belt to the body, and with force limiters which limit the restraint force to a threshhold tolerable to the human being and achieve optimal utilization of available interior space. Such force limiters are available today. Appropriate belt webbing with minimum elongation must be found but with sufficient flexibility to assure proper belt retraction. The previously mentioned pre-loading devices are still in development.
3. By head ride-down during subsequent impact against interior parts which occurs by reason of limited vehicle interior space, for instance against steering wheel and dashboard. Related tests were quite successful, but this success is restricted to specific seat positions, impact directions, and occupant body sizes thereby raising doubts as to correlation with actual accident conditions.

Nevertheless, we believe that occupant protection up to impact speeds of 40 mph can be achieved sooner and more reliably using seat belts rather than air bag systems. As already mentioned the passive restraint systems as presented in our ESV 13 seemed to find encouraging acceptance by the public who are attending Transpo.

During the 2nd International ESV Conference in October 1971, numerous suggestions for the ESV future objectives and their realization were presented by several automobile manufacturers participating in the program. Today at this conference in Washington, as at the previous conference, such suggestions again are welcome. I would like therefore to return to our suggestions concerning a new orientation of the ESV program. They are as follows:

1. ***Discussion of the targets which can be reached in the near future with justifiable utilization of personnel and financial means.*** Only by realistic selection of these targets, will the development proceed in a "good climate" without pressure due to the possibility of sudden, extreme legal requirements. We are anticipating this discussion with the greatest interest.

2. ***Establishment of a step by step plan also for the experimental safety vehicle project, which sets reasonable objectives within sufficient periods of***

time. Daimler-Benz AG has taken a first step in this direction by the orientation of our ESV development to a step by step program which I have already described. The working group "Safety Vehicle" of the German automotive industry will revise the German specifications in this sense, backed by the results of this 3rd International Conference and the latest statistical findings in Germany, and will define a realistic graduation of the development objectives of the ESV program. In order to avoid all misunderstanding, I would like to emphasize that even the step by step plan is an experimental program and should not be considered a development stage of the series production in the near future.

3. *Promotion and extension of bio-mechanical research*. In Germany bio-mechanical research remains in its initial stages. The situation in other countries is only partly known to us. We know that test series with human volunteers have been carried out at Holloman Air Force Base and in Philadelphia and detailed reports of the results of these tests are of great interest to us.

4. *Compilation of statistical data which in particular will clarify the relationship between accident severity and impact speed*. The statistics published recently by the Association of German Motor Vehicle Insurers is a first step in this direction. France is also obviously endeavoring with great zeal to obtain new statistical material which has already produced positive results. The announced revision of the German specifications will take these new statistical results into consideration.

5. *Establishing a well-founded cost/benefit analysis*. Recent and meaningful studies in regard to this subject have not become known to us. Such studies could only be worked out after having established a sufficient internationally coordinated statistical data base. We again appeal to the competent and responsible institutions in all countries to provide the financial and personnel prerequisites for such studies.

As we have learned from the conference program, Thursday will see a discussion of future rule making. For this reason I would like to make some basic statements without going into detail.

The Department of Transportation has declared that it will utilize the results of the ESV project in establishing safety regulations for the future.

We must, however, once again emphasize that the development of automobiles is a long term project. Today the industry is designing the vehicle models which will be produced from 1976 to 1980 and beyond. Therefore, all these rules must be known today which will decisively influence the basic concept and the major dimensions of the vehicles, the dimensional relationships of the passenger compartment and the window openings as well as the interior appointments and the restraint systems.

We very much appreciate that the automobile manufacturers are provided with proposed rule making in due time for examination and comments.

However, according to past experience the time gap between publication of final standards and the effective dates is too short. In other words, what will be required for the 1976/77 model year production must be published in final rule form in 1972, i.e. five years prior to manufacture of the model year.

In the future particular attention should be given to standards concerning handling characteristics. Research today is still far away from making valid statements concerning the driving safety on the basis of individual tests and without the judgment of an experienced test driver.

It is true that every maneuver and every test relate, in some way or other, to driving safety. Mostly simple tests only cover the numerous situations in actual traffic only indirectly and incompletely, and faulty judgments are very difficult to avoid. For this one example: Normal road vehicles which we have modified for test purposes in such a manner that they were in the center of the acceptable range of road holding according to the ESV regulations, have become so unacceptable in some aspects that we would not have released them in this state.

One should therefore be very cautious in the definition of the boundaries between safe and unsafe and the translation of such tests to normal road vehicles satisfactory as a whole but failing with respect to individual boundaries which are established without possessing the required scientific basis.

At this point may I once more mention our engineering procedures which surely in principle correspond to that of other development and research departments of the automotive industry. For more than 30 years — as one of the first safety-minded automobile manufacturers — we have consequently and step by step developed safety features of the Mercedes-Benz vehicles and have incorporated them into series production. The result was a steady, internationally recognized increase of the safety level of our products. Even so, the development of a special experimental vehicle was included in our engineering program, which could then logically be based upon the standard of the series production vehicles.

Consequently, our experimental safety vehicle contains several features which are not mentioned by regulations or by the ESV specifications, as for instance, the anti-block system, and measures taken against dirt build-up on headlights and windshields. These substantial developments are already part of the series production vehicles of our company or will be introduced shortly.

Daimler-Benz AG will continue to contribute its part to the increase of safety of human beings in road traffic. We recognize the necessity of close cooperation and welcome international meetings such as this 3rd ESV Conference in Washington. I would like to thank the organizers in particular and compliment them on the excellence of the arrangements and the program. May I close my remarks with the hope that at the end of this conference we shall all clearly recognize the future objectives of the ESV Program and be able to better integrate these objectives in our planning than has been possible to date.

GERMANY

DR. K. BRUMM, *Chief*

Research Department
Adam Opel A.G.

OPEL'S CONCEPT FOR A SAFETY-VEHICLE OF THE LOWER WEIGHT CAR CLASS

Ladies and gentlemen,

As an introduction I would like to briefly repeat some of the objectives of our work as presented at the 2nd ESV Conference in Sindelfingen last year.

In the first phase of our ESV program we concentrated our work in meeting the 2,000 pound ESV specifications as issued by the German Autmobile Manufacturers Association which are similar to the 4,000 pound U.S. ESV requirements.

Our studies indicated that a vehicle designed to meet all these specifications would no longer be a 2,000 pound car but rather a vehicle of the European upper medium car class. We actually ended up at 2,600 pounds of curb weight.

Continuing with this concept we would not only have exceeded the weight limit by far but also would have neglected the safety research and development on vehicles in the lower weight car class up to 2,200 pounds representing about 70% of all passenger vehicles on European roads.

After an intensive study of statistical material on traffic accidents we adjusted the requirements for a 2,000 pound vehicle according to our findings and based on our new design targets on actual traffic accident conditions wherever possible.

As a result of this study we started phase two of our ESV program in June 1971 following the list of specifications as outlined in our presentation during the last ESV Conference. The main objectives of our ESV program are based on an upper weight limit of 2,200 pounds, the use of conventional materials, and keeping in mind the possibility of high volume production.

PHASE 2

UPPER WEIGHT LIMIT: 2200 LBS MATERIAL: CONVENTIONAL MANUFACTURING: HIGH VOLUME PRODUCTION

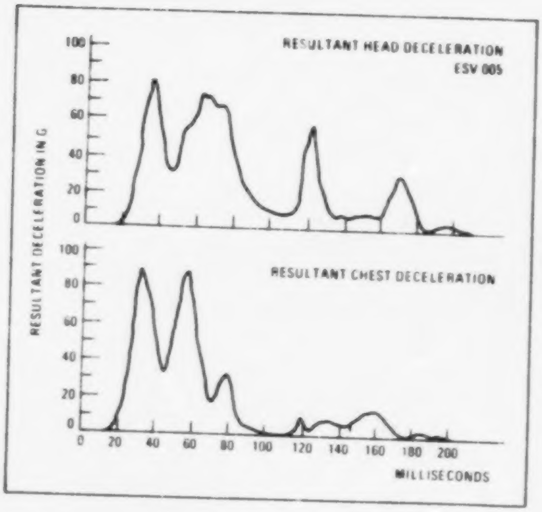
Since the last status report given at the 2nd ESV Conference in Sindelfingen we have successfully built and tested another three vehicles.

CONDUCTED TESTS

ESV 003	50 MPH	FRONT, BARRIER
ESV 004	35 MPH	REAR, MOV. BARRIER
	12 MPH	SIDE, MOV. POLE
ESV 005	50 MPH	FRONT, BARRIER
	10 MPH	REAR, MOV. POLE
	35 MPH	REAR, MOV. BARRIER
	12 MPH	SIDE, MOV. POLE
	VEHICLE FULLY LOADED	

The test vehicle No. 6 tested in a 50 mph barrier impact shortly before this conference is not included in this listing. It is interesting to note, that with the increasing number of test vehicles also an increasing number of tests could be performed with the same vehicle without going through a repair phase. Both vehicles ESV No. 5 and No. 6 were below the curb weight target of 2,200 pounds and have been tested with full load.

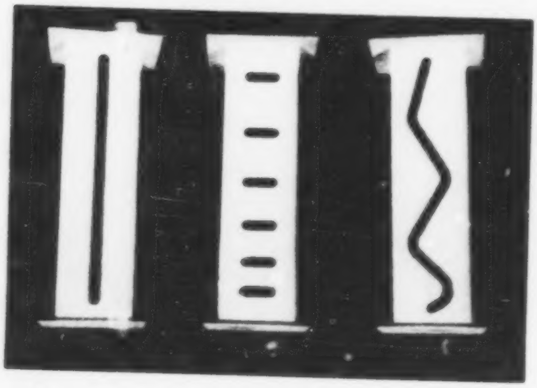
With ESV No. 5 we were able to obtain the following resultant head and chest deceleration data shown on this slide. We exceeded the head "g" limit of 80 "g" slightly and the specified 60 "g" for the chest by about 10 ms.



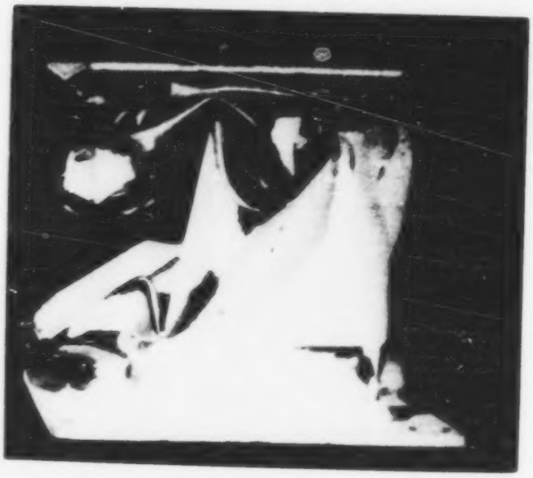
For further improvement of the injury data we have continued our development work in the energy management and occupant protection field as will be outlined and illustrated with a short movie later.

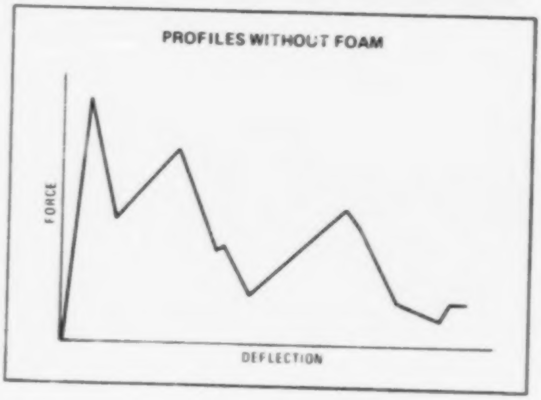
1. ENERGY MANAGEMENT

On our search for combined light weight and high energy absorbing structural elements we investigated members of different shapes, dimensions and bead configurations in an attempt to achieve an optimized force-deflection characteristic.



Dynamic testing of these profiles indicated the necessity to determine other methods for achieving this goal since the uncontrolled buckling process did not furnish us with the expected results.





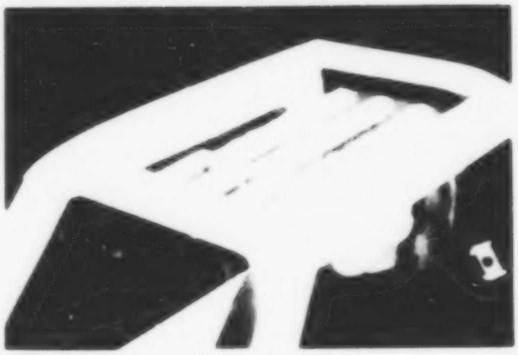
For controlling the buckling process we investigated hard foams of different properties in combination with various sheet metal profiles and thicknesses.

After performing a series of tests we obtained very promising results with the two profiles on the right side of the slide.

The following short movie demonstrates the work accomplished to date. The experience gained with these simplified frame members and front ends will be applied in the design of the vehicle structures of our future test vehicles. Filling the vehicle structure with foam not only enables high energy absorption in combination with the sheet-metal but also prevents internal corrosion and acts as noise and vibration damper. The effect on floatability has not yet been studied.

2. OCCUPANT PROTECTION

As a further tool to reduce the g-levels of the occupant we intend to make use of the interior space for additional energy absorption with an E/A seat back. The energy absorption gained with this design prevents further elongation of the front end.

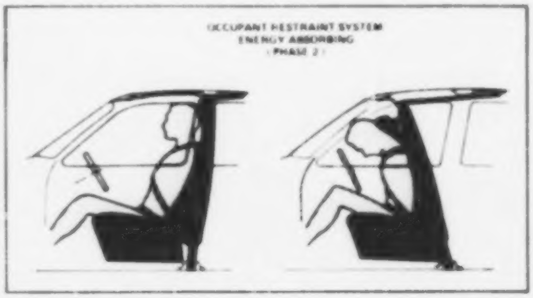


It should be mentioned that we are concentrating on belt-systems of different designs connected to the seat back.

To accelerate the fundamental development work we installed available components as the E/A source for the back of our test seat.

The following short movie demonstrates the status of the work in this field.

Other energy absorbing elements are in the stage of laboratory testing.



Besides the E/A seat back shown in the movie we are also investigating a design with moving head rest following the head in the forward movement to prevent any rebound motion which can result in higher severity index numbers.

Summarizing the first two segments of this presentation we are quite confident of being able to build an ESV according to our specifications adjusted to actual accident statistics as outlined broadly during the last ESV conference.

3. ACCIDENT AVOIDANCE

Besides the work in the energy management and occupant protection field we have also taken a closer look at the subject of accident avoidance. Initial test and evaluation of production vehicles indicated that we were already close to meeting the ESV requirements. In a second step we modified an Opel 1900 production vehicle to further improve our ability to meet final target.

We also modified the front and rear end of this vehicle to illustrate the bumper system proposed for our ESV.

This bumper system fits well to the structural concept of our ESV and results in a good force distribution. It also takes care of the over and under riding problem and provides front and rear lamp damage protection during low speed impacts. The bumper system shown has been designed for collisions up to 5 mph. Deformable E A units take care of the energy up to 10 mph before the vehicle structure starts to buckle.

The vehicle shown in these slides has been used for accident avoidance testing.

For demonstrating steerability during braking in a curve we installed a Teldix 4 wheel skid control system into this vehicle. Besides this system we are also evaluating and testing the different systems of GM and other companies.

Concluding this presentation we are in a position to state that based on the encouraging achievements in the three main areas of energy management, occupant protection and accident avoidance we believe we are on the right track in achieving our goal of developing a safety vehicle in the lower weight car class.

Energy Management and occupant protection are ranking on top of our priority list in the ESV program. Accident avoidance work follows with lower priority.

Our efforts of adjusting our inhouse ESV specifications according to the latest traffic accident statistics will be continued to optimize our design. It should be mentioned again that the development shown is another step in the direction toward meeting our objectives but a significant amount of work is still ahead of us before reaching the point where a high volume production design has been achieved.

Thank you very much.

GERMANY

DR. ERNST FIALA
Head of Research and Development
Volkswagenwerk AG

ESVW

SLIDE 1

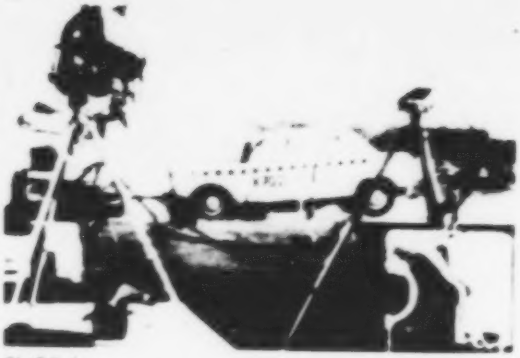
Volkswagen began its experimental safety vehicle program in the fall of 1970. Involved in our activity have been 80 engineers and technicians plus many times that number in construction of components, test frames and of the complete vehicle, which we call the ESVW. (Slide 1)

SLIDE 2

To provide performance data during the ESV development stage we modified two of our company's normal production cars: one, the front-engined, front-wheel-drive Audi 100 and the other, the rear-engined, rear-wheel-drive VW 411. These vehicles were used for the various handling and accident-avoidance tests. They were modified to reproduce the weight distribution, dimensions, engine output, axles and curb weight of the ESVW. (Slide 2)

We conducted 14 destructive and 6 non-destructive tests, using crash-test frames that have force-deformation characteristics similar to the ESVW. (Slide 3)

SLIDE 3

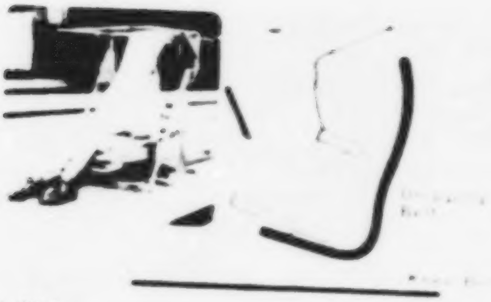


SLIDE 4

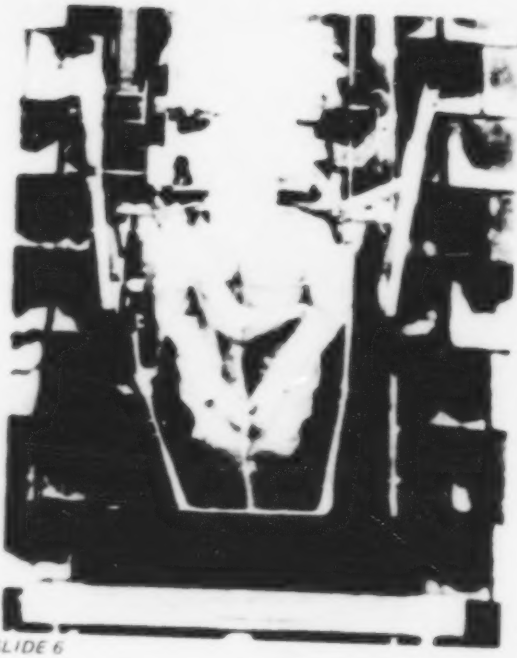
We also conducted forty crash tests using production cars modified with ESV components (Slide 4).

In the development of our restraint system, we conducted 420 sled tests to evaluate air-bag performance as well as various belt performance. Early in the development, when we were concerned about head acceleration, we ran tests with various head restraint systems including a dropping chest belt and net (Slide 5).

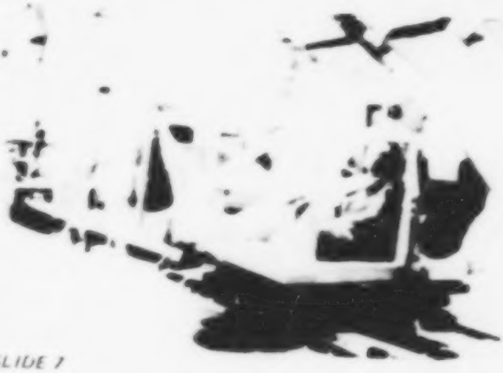
We finally settled on a passive shoulder belt and knee belt system similar to the one shown here (Slide 6).



SLIDE 5



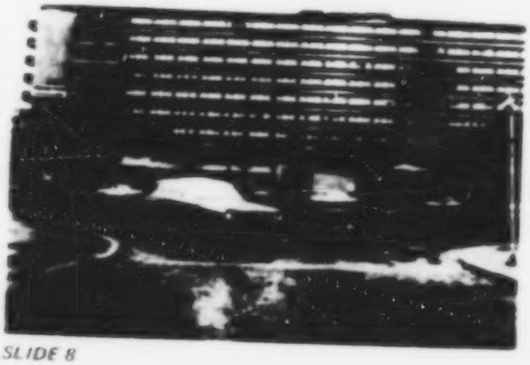
SLIDE 6



SLIDE 7

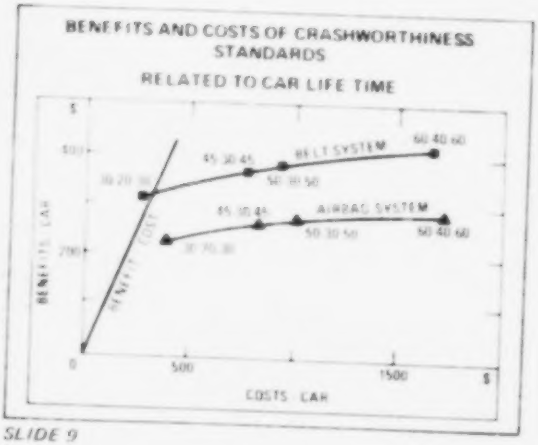
Deformation characteristics of the passenger compartment were tested in many sled tests using ESV crash-test frames. (Incidentally, we tried very hard to come up with a more precise name for this unit than "crash-test frame" but could find none better. One suggestion, which we discarded after some discussion, was that we name it in honor of our friend Doug and call it "Uncle Toms' Cabin.")

Numerous crash tests into poles and barriers were conducted with our high-energy hydraulic bumper system. All this testing and development have resulted in the car I will discuss today, the ESVW (Slide 7).



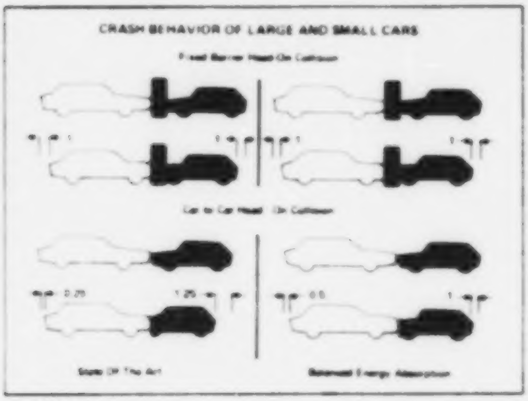
SLIDE 8

This Volkswagen experimental safety vehicle is compatible with today's normal traffic. It does not look out of place on the highway. It had its first public showing at Transpo 72 last week. I hope you will give it close inspection when you visit the ESV dome (Slide 8).



SLIDE 9

While we were working on the practical testing and production of the ESVW, we made a thorough but theoretical investigation into the benefits and costs of the ESV specifications. I will come back to this slide later (Slide 9).


CRASH BEHAVIOR OF LARGE AND SMALL CARS
Fixed Barrier Head-On Collision
Car to Car Head-On Collision
0.25
1.25
0.5
1
State Of The Art
Balanced Energy Absorption

SLIDE 10

We also investigated the problem of crashworthiness in real-world traffic with its variety of vehicles, large and small. This investigation has led us to a suggestion for tailoring force-deformation characteristics to vehicle weight.

In the current state of the art, the large car and the small car have the same crash behavior when each is crashed into a fixed barrier at the same speed. In a car-to-car head-on collision, however, the large car has a 5:1 deformation advantage over the small car. In the solution which we are suggesting, a balanced energy absorption design would be used to reduce this large car advantage to something on the order of 2:1. Our tests show that this can be accomplished.

At the conclusion of my presentation, I will show you a movie of many of the crash tests I will discuss in the next few minutes (Slide 10).

PERFORMANCE

- ACCIDENT AVOIDANCE
- CRASHWORTHINESS
- PEDESTRIAN SAFETY
- COMFORT

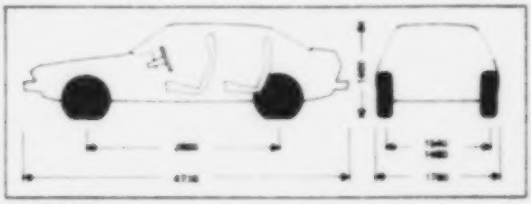
WEIGHT

PRICE

ESV GOALS

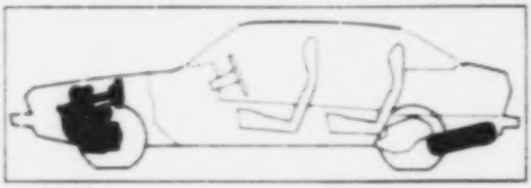
SLIDE 11

Very early in our work, it became clear that to fill all ESV performance specifications, and to keep under the 2,000-lb. weight limit, would require exotic materials, with a high strength-to-weight ratio. This would bring high costs, both in material and production. We decided not to go in the direction of exotic materials and exorbitant costs, but rather to produce as realistic a car as possible so as to gain as much practical knowledge as possible. The result, we think, is a high-quality, relatively low-priced vehicle, consistent with the concept of Volkswagen's production cars (Slide 11).



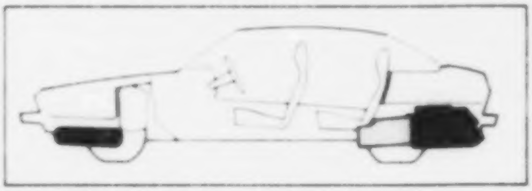
SLIDE 12

The ESVW is a four-door sedan for four occupants, with the rear seat being designed for 50-percentile males. Curb weight is 3,200 lbs. Wheel base is 110 inches. Overall length is 186 inches. Front track is 60 inches and rear track is 58.3 inches. Overall width is 70 inches. Overall height is 54 inches (Slide 12).



SLIDE 13

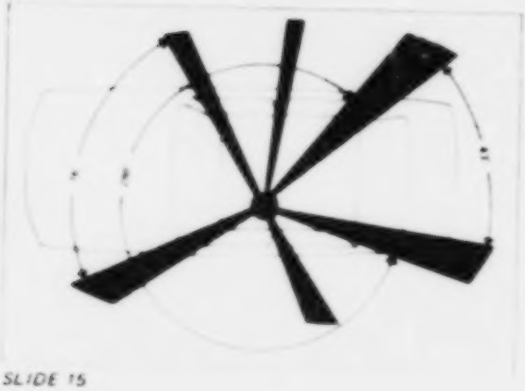
We have also developed a second ESVW which we have not yet constructed — one with a transverse front engine. In this version the fuel tank is located between the rear wheels with the spare tire just behind it (Slide 13).



SLIDE 14

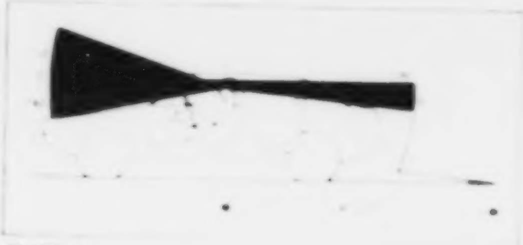
The ESVW that I will discuss today has an air-cooled rear engine. Fuel tank is located between the front wheels with the spare tire in front of and below it (Slide 14).

The driver's angle of vision on the horizontal is 76 degrees forward and 43 degrees rearward. There are four pillars within 288 degrees (Slide 15).



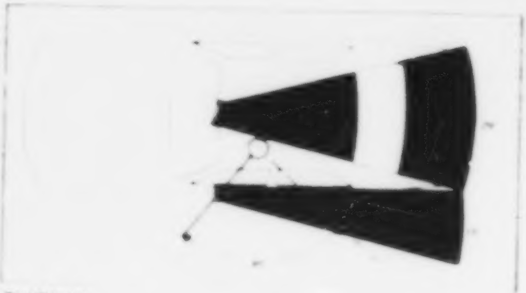
SLIDE 15

The driver's angle of vision on the vertical is 17 degrees above the horizontal, and 3 degrees under the rear-view mirror. Below the horizontal, the angle of vision is 7 degrees 40 minutes. Using the inside mirror the rear angle of vision is 1 degree 30 minutes above the horizontal, and 5 degrees below the horizontal. The closest road surface that can be seen is 41.2 feet behind the driver. The front seat is fixed and has a height adjustment for the driver, creating a very small eye ellipse (Slide 16).



SLIDE 16

On the horizontal, using the inside mirror, the angle of vision is 29 degrees with 15 degrees added by the outside mirror. The 85-degree angle defines the peripheral vision available to the driver when he is using the outside mirror (Slide 17).

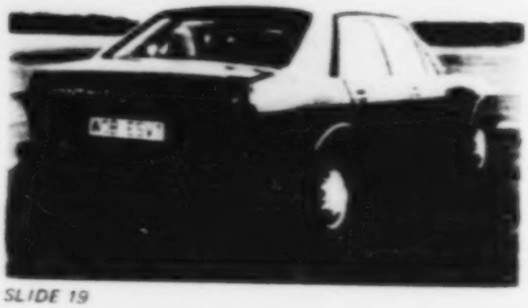


SLIDE 17

SLIDE 18

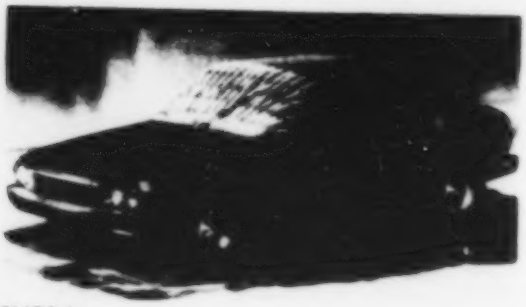
The styling is, in our opinion, functional and neat. It was influenced to a large degree by the angle of vision and crashable length requirements (Slide 18).

as well as the aerodynamics requirement that windows and lights be kept clean. The drag coefficient for the design is 0.36 as calculated from wind tunnel tests of the 1:4 model (Slide 19).



SLIDE 19

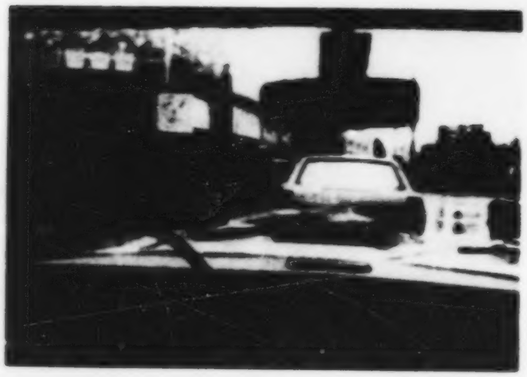
A single windshield wiper keeps the blade always close to the air stream, thus the air movement helps remove the water and does not cause blade lifting at high speeds. We also have a washer-wiper system for the four headlights. Top and sides of the turn signals are kept free of dirt by the air flow (Slide 20).



SLIDE 20

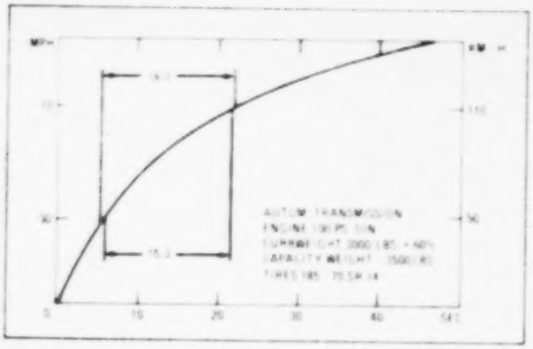
At the rear, there are four green tail lights or running lights. Two are just above the bumper, and two are near the upper corners of the rear window. The red brake lights are of a two-step design and flicker rapidly during hard braking to alert following drivers to sudden deceleration. A gradual brake application gives a non-flickering light. The rear turn signals are amber. All lights have a dual-intensity feature, which makes them brighter under fog conditions. In normal daylight, the turn signals and brake lights also have a brighter intensity than at night.

The location of the stop lights atop the rear quarter makes them visible to following cars even if another car comes between. The four green tail lights, widely separated in two dimensions as they are, provide following drivers with a most effective means of estimating distance (Slide 21).



SLIDE 21

The ESVW, with a 100 horsepower DIN engine and automatic transmission, accelerates from 50 to 110 kilometers-per-hour in 15.3 seconds and from 30 to 70 miles-per-hour in 16.3 seconds (Slide 22).

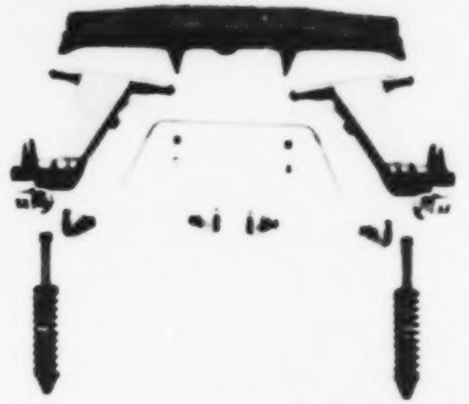


SLIDE 22

Front and rear suspensions are similar to those on our production model — the VW 411 (Slide 23).

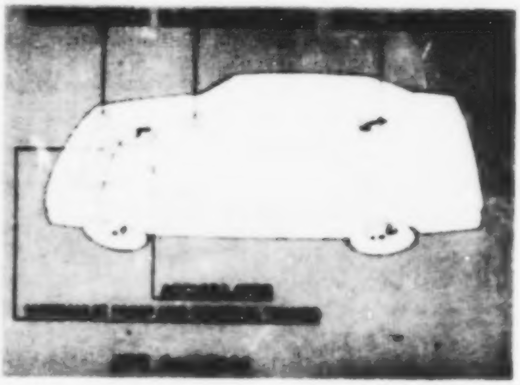
SLIDE 23

The ESVW has power-assisted disc brakes on all wheels (Slide 24).



SLIDE 24

It has an ATE — Teves anti-skid system with independent front wheel control and a "select low" at the rear. The red lines show the wiring which relays vehicle speed information from the sensors to an electronic module which controls brake application. The black lines are the brake lines (Slide 25).



SLIDE 25

The ESVW has an advanced version of the electronic diagnosis used in our production vehicles. The socket is in the front compartment (Slide 26).

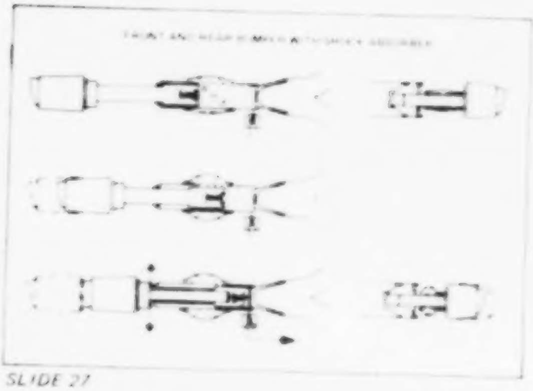
SLIDE 26

Front bumpers (shown here on the left) are of high-strength steel, 0.14 inch thick. The bumper absorbs a 10 mile-per-hour impact without damage and restores itself after a 3.5 inch stroke. In a high-speed crash the total stroke is 8 inches.

On low-speed impact, the fluid is forced through a series of holes and retained inside an expanding rubber sleeve. After impact, the fluid is forced back into the cylinder and the bumper returns to normal position.

On impacts of over 10 miles-per-hour, a metering valve inside the piston opens and releases the fluid to the outside. A switch operates when pressure exceeds 2500 psi and fires the preloading device in our restraint system.

The rear shock-absorbing bumper (on the right) is similar, with a rubber sleeve that absorbs a 5 mile-per-hour impact. It has a 2-inch stroke and, like the front bumper, is self-restoring (Slide 27).

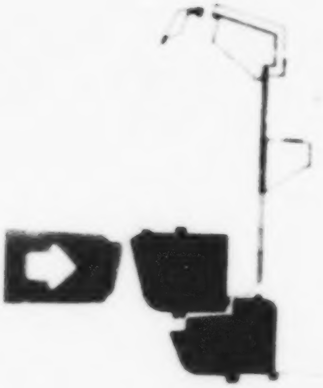


SLIDE 27

This cutaway bumper shock absorber lets you see how the rubber sleeve is attached and the size and location of the holes that release the fluid. Also cut away is the metering valve which opens on high-speed impact, allowing the fluid into the piston and out to the atmosphere (Slide 28).

SLIDE 28

Side impact bumpers are built into the lower edge of the doors at a height matching the front bumper of an impacting vehicle. The bumpers are of high-strength steel, 0.1 inch thick and are approximately 5 inches by 6 inches. Other side impact protection is provided by the parts shown in blue (Slide 29).

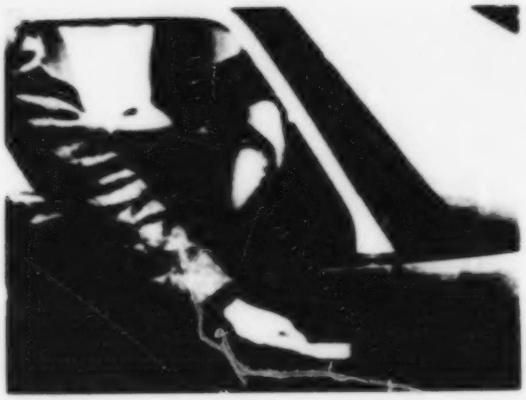


SLIDE 29

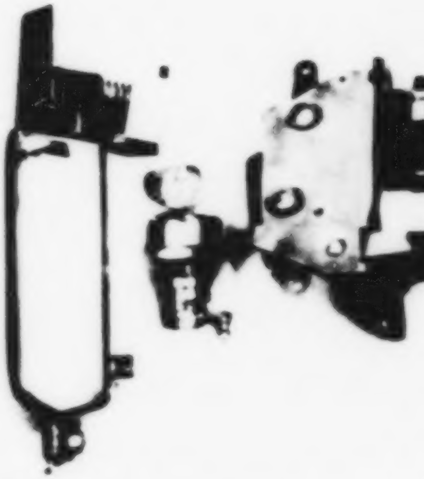
Door latches are pulled to open (Slide 30).

The latch mechanism is counter-balanced to prevent unintentional release by inertia loading. The latch is effective for forces of 7,000 pounds (Slide 31).

The passive restraint system for all passengers consists of a shoulder belt and a knee belt with the preloading mechanism located in the central tunnel. Each has a force limiter, one on the shoulder belt and another built into the door for the knee belt. In our opinion, this is the most effective and reliable restraint system.



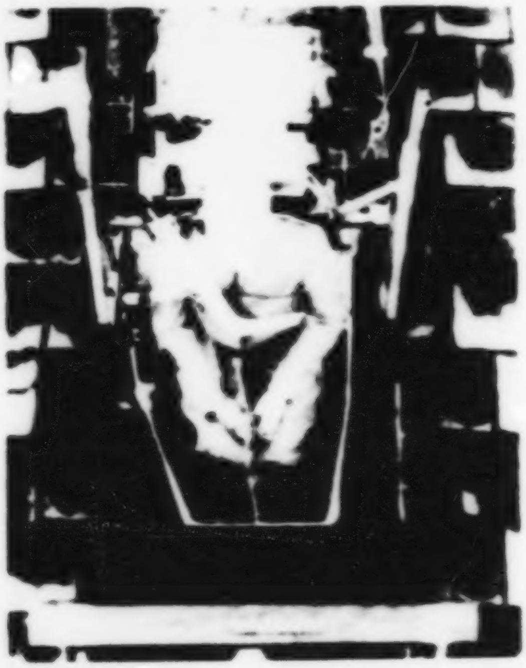
SLIDE 30



SLIDE 31

Upon signal from the pressure switch in the front bumper hydraulic unit, a cartridge is fired and the piston is accelerated to 160 mph. The piston rod removes the slack from the shoulder belt and deploys the knee belt within less than 10 milliseconds. The preload given to each belt is about 400 pounds (Slide 32).

This is the preload cylinder and piston. The belt attaches to the loop at the end of the rod. Maximum stroke is 400 millimeters—or 16 inches. In the enlarged view, you can see that the cartridge is located inside the piston. When it fires, the gas pressure drives the piston to the right at a nearly constant speed of 160 mph. A non-return lock (shown in yellow) retains the piston at the end of its stroke, maintaining the load on the belts (Slide 33).



SLIDE 32

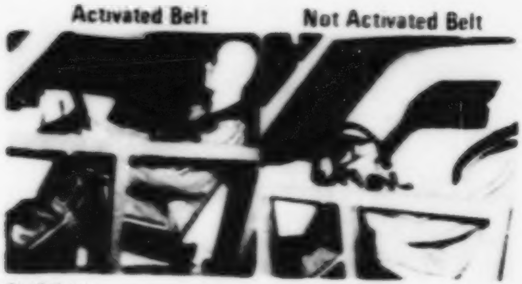
SLIDE 33

In the normal driving position, the tubular form of the shoulder belt makes it self-supporting and keeps it a few inches away from the driver. The amount of slack is about 6 inches.

The knee belt is concealed below the dashboard and becomes visible only when deployed during impact above 15 mph.

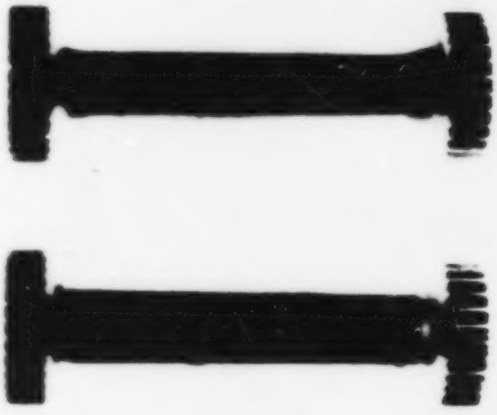
For the crashes below 15 mph comparable-barrier-speed, the cartridge does not fire. The shoulder belts are sufficiently effective to restrain the occupants. An additional advantage of this restraint system is that it keeps the occupants in correct position at all times, an important factor for any restraint system (Slide 34).

A force-limiting torsion bar is part of both shoulder belt and knee belt systems. It undergoes



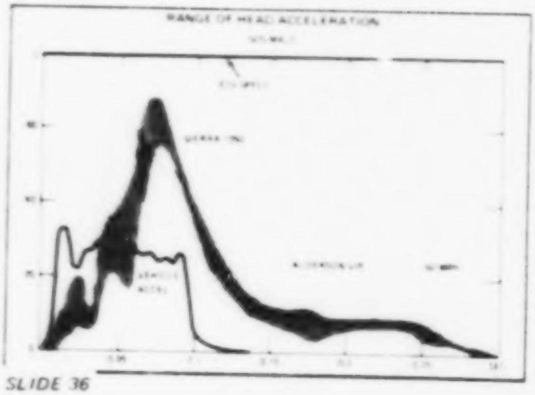
SLIDE 34

plastic deformation to keep the belt force below 1300 pounds (Slide 35).



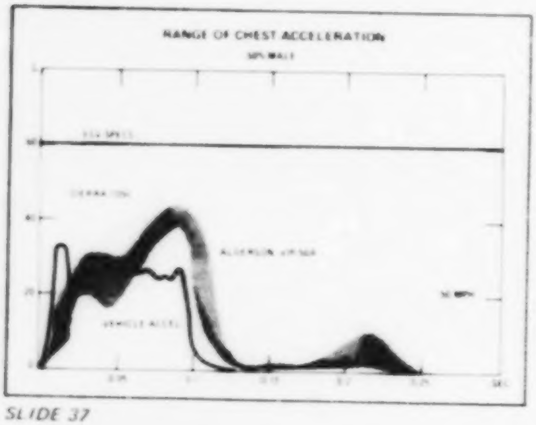
SLIDE 35

In a sled test at 50 mph with a mean sled deceleration of 25 g's the ESVW gives a resultant head acceleration of about 60 g's. The dark curve gives the range of three shots with an Alderson dummy while the light curve gives the range of four shots with a Sierra dummy. These were with a 50 percentile male (Slide 36).



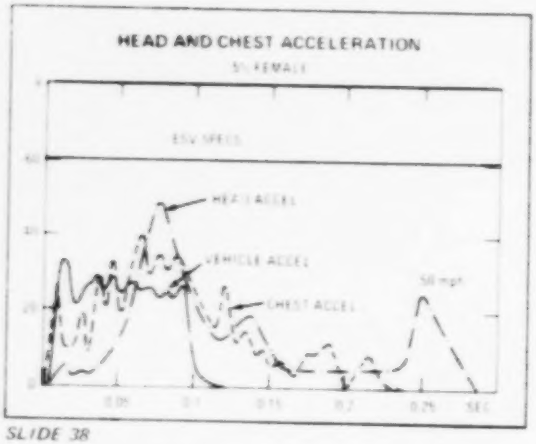
SLIDE 36

The resultant chest acceleration is about 40 g's (again the dark curve is Alderson and the light curve is Sierra). The femur load with each dummy is about 1,000 pounds.



SLIDE 37

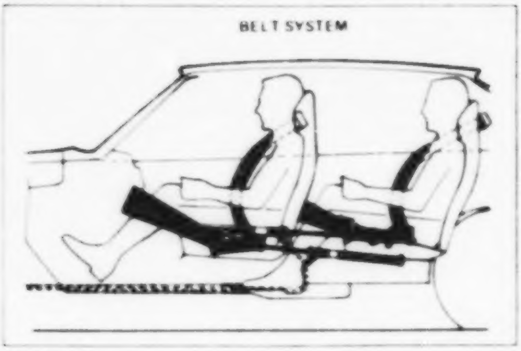
The belt geometry provides a self-regulating adjustment to occupant's weight, based on occupant dimensions. This gives us about the same results for a 95 percentile male and a 5 percentile female. Shown here is a curve based on one shot with a 5 percentile female (sled, head and chest at 50 mph) (Slide 38).



SLIDE 38

For each of the four occupant-restraint systems, one preloading device is located in the central tunnel, outside the passenger compartment. Thus the cartridge firing does not produce noise or pressurization problems (Slide 39).

The ESVW restraint system is completely passive. However, we believe that the difference between active and passive restraints is more a question of convenience than of safety.



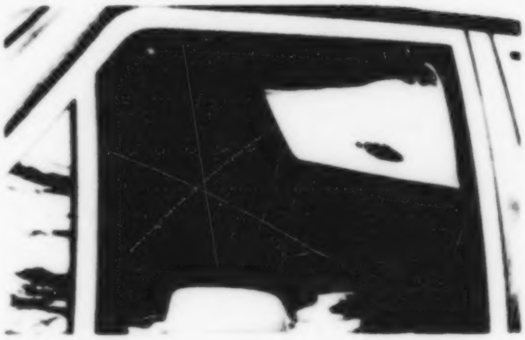
SLIDE 39

After the door closes and the engine is started, the upper end of the shoulder belt which includes the force limiter is moved along a track to the B pillar by a vacuum-powered device. The knee belt is concealed behind a breakaway seam (shown here in white). The seam is forced open when the preload mechanism operates, deploying the six-inch-wide knee belt. The shoulder belt is foam-filled and has a tubular shape to eliminate any possibility of twisting or injury caused by sharp edges (Slide 40).

SLIDE 40

After the crash, tension on both belts is released by a single pushbutton at the upper end of the shoulder belt. The inner plastic partial-window prevents head ejection in a rollover should the window be open or broken (Slide 41).

For rear occupants, the knee belts are hidden behind the upholstery on the fixed front seat back. A padded separation between the seats at shoulder level prevents lateral movement. A first-aid kit is located in a compartment above the tunnel. Rear windows are



SLIDE 41

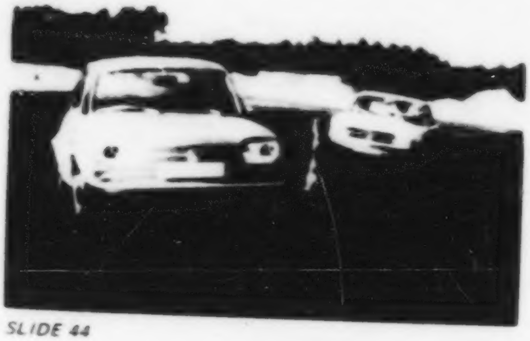
SLIDE 42

fixed — the front seat backs are welded to the body structure to form a transverse bulkhead (Slide 42).

Because all seat backs are fixed, the steering wheel and pedals adjust to the driver by a pushbutton-operated electric motor. Less range of movement is required for the steering wheel than for the pedals. The driver seat cushion can be raised to provide adequate vision for short drivers (Slide 43).

SLIDE 43

For early tests of handling, modified production cars were equipped with the same engine, running gear, wheelbase and tread of the ESVW. Both rear-engined and front-engined vehicles gave results well within the limits of the ESV specifications. In our opinion, however, much more investigation must be made before a truly effective handling specification can be written (Slide 44).



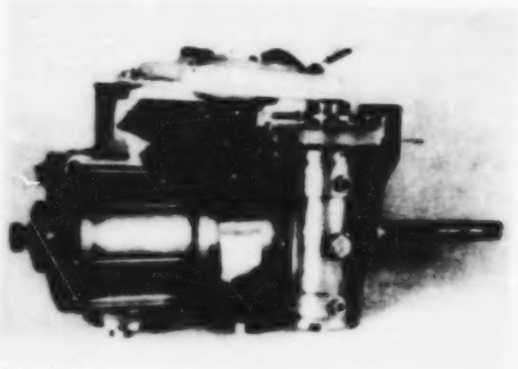
SLIDE 44

A device, which we call the "silent copilot," sharply reduces side-wind deviation and markedly improves transient response. An accelerometer, located in the center front, measures side acceleration. The electronic control unit compares that acceleration with the steering-wheel angle. If the steering-wheel angle is zero but side acceleration is not (as when the car direction is changed by side wind) the control unit orders the servo unit to turn the front wheels to compensate. Or if the steering-wheel angle is not zero and the car continues to go straight the device increases the front-wheel angle. By measuring the dynamic behavior, the silent copilot adjusts the steer-angle of the wheels to correct the transient and stationary vehicle response (Slide 45).

CONTROL UNIT
SERVO UNIT
SENSOR FOR LATERAL ACCELERATION
STEERING WHEEL MOTION
ADAPTER

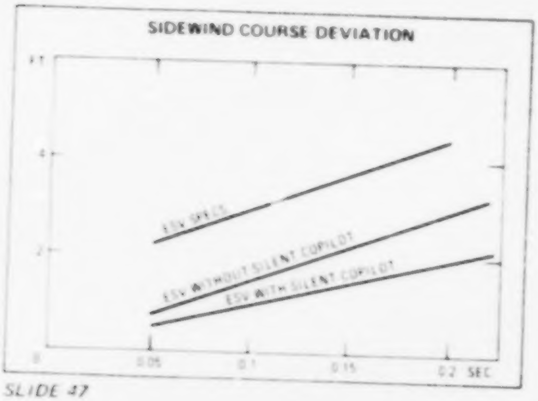
SLIDE 45

The servo unit is a flat electric motor attached to the steering gearbox (Slide 46).

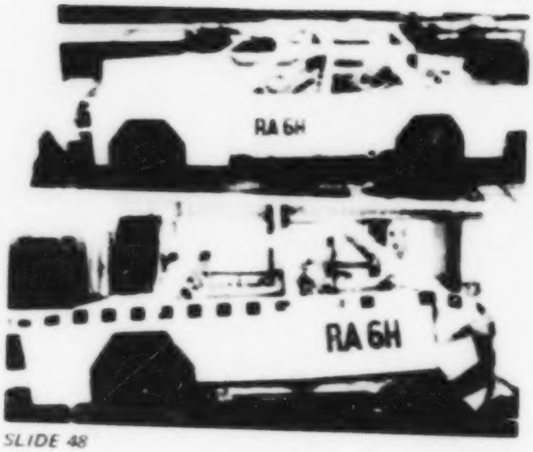


SLIDE 46

Side-wind deviation is reduced well below ESV specifications with the silent copilot. Even without the silent copilot, the ESVW meets ESV specifications (Slide 47).



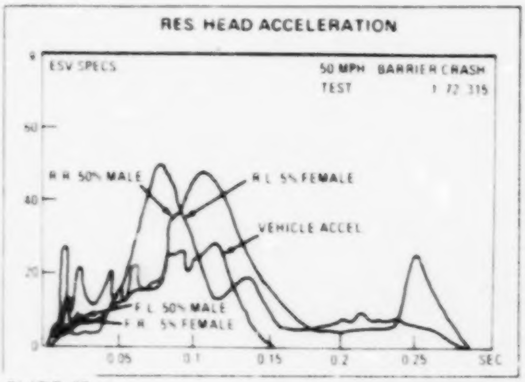
SLIDE 47



SLIDE 48

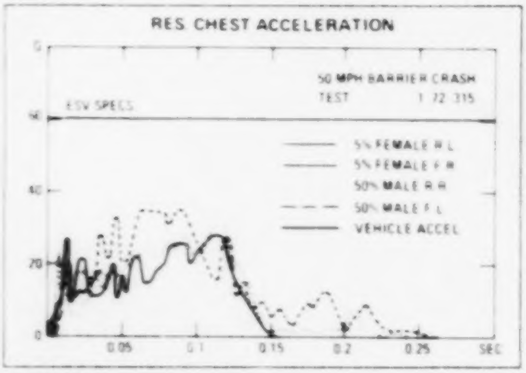
Test crash frames which duplicate the stiffness and rigidity of the ESVW were used to test crash performance. That allowed us to make quick and inexpensive changes after each test. The front structure was designed to bend downward bringing the front bumper shock absorber into a vertical position, providing added stopping distance (Slide 48).

In a 50 mph barrier crash, the mean vehicle deceleration was 20 g's, the resultant head acceleration 50 g's for 50 percentile male and 5 percentile female. All values are filtered with 100 cycles per second (Slide 49).



SLIDE 49

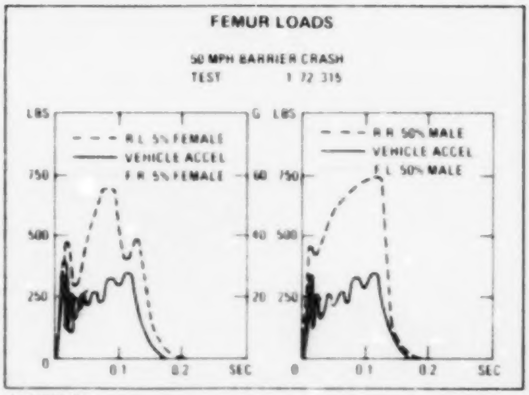
Resultant chest acceleration was below 40 g's (Slide 50).



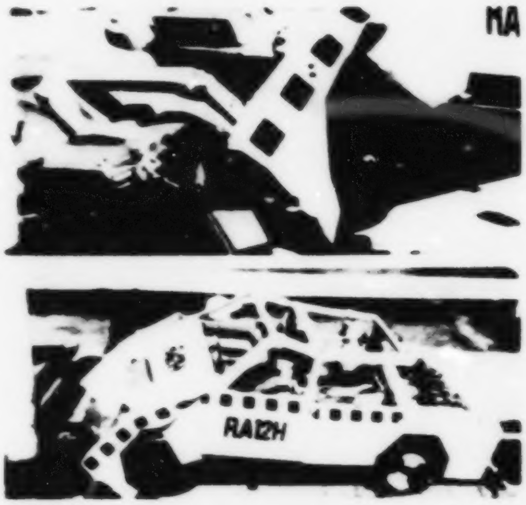
SLIDE 50

Femur loads were less than 750 pounds (Slide 51).

A 50 mph pole crash also demonstrated the way in which the front structure bends downward. The gas tank, located between the front wheels remained intact (Slide 52).



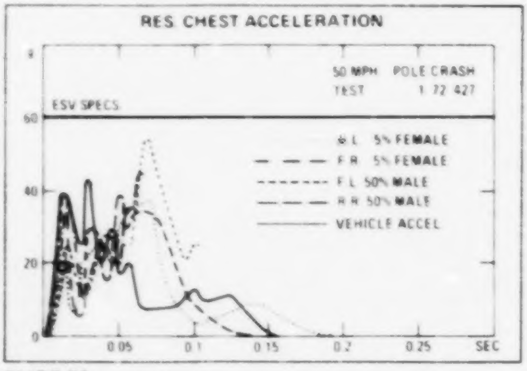
SLIDE 51



SLIDE 52

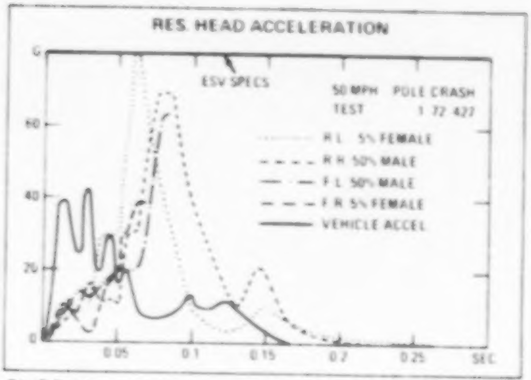
In the 50 mph pole crash we have acceptable chest acceleration for the Front Left 50 percentile male, Front Right 5 percentile female, Rear Left 5 percentile female and Rear Right 50 percentile male (Slide 53).

One dummy, the Rear Left 5 percentile female, developed more than 80 g's in the head for some



SLIDE 53

milliseconds. The reason was too high friction in the belt system (Slide 54).



SLIDE 54

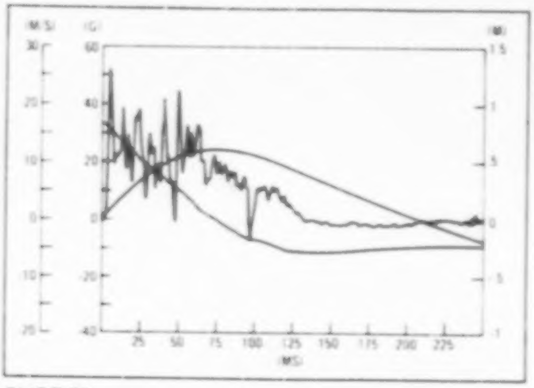
For vehicle-to-vehicle tests, we used a moving barrier or "big vehicle" of 5500 pounds (2500 kilograms) (Slide 55).

SLIDE 55

SLIDE 56

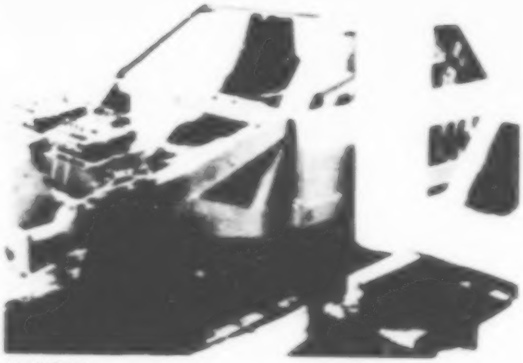
This big vehicle-small vehicle test crash gave similar data in the crash force-impact speed ratio to those we outlined in Stuttgart, concerning mixed big-small vehicle accidents. We conducted a head-on crash between a modified production car and the "big vehicle" with both moving at 37.5 mph, giving a speed differential of 75 mph (Slide 56).

The data showed a velocity change of 50 mph for the smaller car and a desirable acceleration time-history. We will show high speed films of this test at the end of this presentation (Slide 57).



SLIDE 57

The 15 mph side impact into a pole gave a maximum vehicle deceleration of 15 g's, an exterior deformation of ten inches and a maximum intrusion of 4.3 inches. Maximum dummy accelerations were about 40 g's for the head, 25 g's for chest and 34 g's for the pelvis (Slide 58).

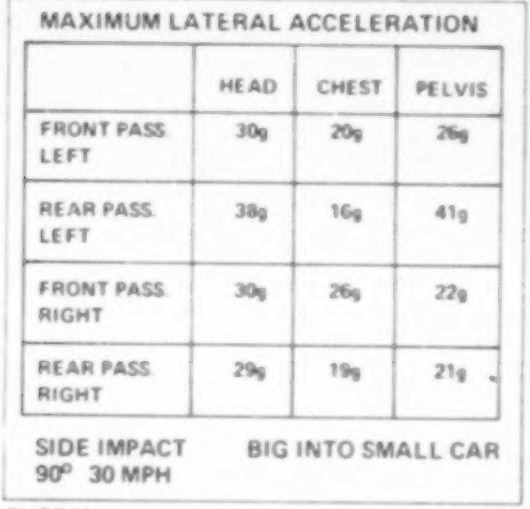


SLIDE 58

The car-to-car 30 mph side impact was also performed with the 5500-pound "big vehicle." Maximum acceleration was 12 g's, exterior deformation was 7 inches and maximum intrusion less than three inches (Slide 59).

SLIDE 59

Maximum accelerations of the four dummies in the small car are shown in this slide for head, chest and pelvis (Slide 60).



MAXIMUM LATERAL ACCELERATION

	HEAD	CHEST	PELVIS
FRONT PASS. LEFT	30g	20g	26g
REAR PASS. LEFT	38g	16g	41g
FRONT PASS. RIGHT	30g	26g	22g
REAR PASS. RIGHT	29g	19g	21g

SIDE IMPACT
90° 30 MPH

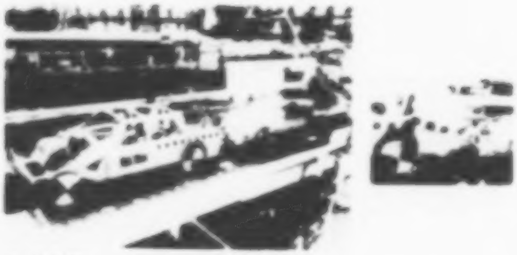
BIG INTO SMALL CAR

SLIDE 60

One test was performed with a 45-degree side impact of 33 mph by the "big vehicle" against the ESVW. The maximum acceleration was 5 g's, exterior deformation was 6 inches and intrusion was 2.4 inches. Dummy acceleration was about 20/15/15 (Slide 61).

SLIDE 61

A rear-end impact by the "big vehicle" was performed at 43.5 mph. Resultant head accelerations were about 40 g's. Chest and pelvis accelerations were 30 g's. Vehicle deformation was 10 inches with no intrusion (Slide 62).



SLIDE 62

In this summation of average accelerations (Slide 63), the shaded areas show the ESVW performance. The U.S. specifications are on the left with German specifications on the right. In a frontal impact into a fixed barrier at 50 mph, the ESVW produced 28 g's with 40 g's being the U.S. requirement.

In head acceleration, the ESVW produced 60 g's against U.S. and German specifications of 80 g's. Chest acceleration of the ESVW was 42 g's against 60 for the U.S.-German specifications. Pelvic acceleration is 50 g's for the ESVW, against 60 for both specifications. Femur load for the ESVW was 300 kilograms or 660 pounds against the U.S. specification of 1400 pounds and the German specification of 635 kilograms.

In side collisions with large and small cars at 30 mph, the head acceleration on the ESVW was 39 g's against 40 for the U.S. and 80 for German specifications. Chest acceleration for ESVW was 30 g's which exceeded the U.S. specification of 20 but was well under the German specification of 60. In pelvic acceleration, the ESVW was 30 g's exceeded the U.S. specification of 20 but was well below the German specification of 60.

As we have stated previously both in Stuttgart and in Washington, we believe that the U.S. specifications for side-impact accelerations are not realistic.

In rear-end impacts of large car into small car at 40 mph, the ESVW did better than specifications in all categories. In car deceleration, the ESVW had 25 g's against U.S. specifications of 40. In head acceleration, the ESVW had 50 g's against U.S. and German specifications of 80. In chest acceleration, the ESVW had 35 g's against U.S. specifications of 40 and German specifications of 60. In pelvic acceleration, the ESVW had 38 g's against the U.S. 40 and the German 60 (Slide 63).

VW TEST RESULTS	DECELERATION CAR	ACCELERATION HEAD	ACCELERATION CHEST	ACCELERATION PELVIC	FEMUR LOAD
FRONTAL IMPACT FIXED BARRIER 50mph COLLISION	USA 40 g 28 g	USA 80 g VDA 80 g 60 g	USA 60 g VDA 60 g 42 g	USA 60 g VDA 60 g 50 g	USA 1400 lb VDA 635 kg 380 kg
SIDE COLLISION LARGE - SMALL CAR 30mph		VDA 80 g USA 40 g 39 g	VDA 60 g USA 20 g 30 g	VDA 60 g USA 20 g 30 g	
REAR END COLLISION LARGE - SMALL CAR 60mph	USA 40 g 25 g	USA 80 g VDA 80 g 50 g	USA 40 g VDA 60 g 35 g	VDA 60 g USA 40 g 30 g	

SLIDE 63

We believe that our ESVW is a practical automobile which meets or exceeds the ESV specifications. We feel certain of this based on the many tests we have conducted with ESV prototypes and dummies and modified vehicles. On the other hand, the weight of the ESVW is about 750 pounds or 30% more than that of a conventional car of the same size. This weight increase costs, makes fuel consumption higher and emission volume greater, especially in city driving (Slide 64).

SLIDE 64

The additional retail price increases for such a vehicle in our estimate would be as follows:

- $1,100 for accident-avoidance devices such as anti-skid brakes and silent copilot;
- $1,000 for a radar warning device which is now installed in the present ESVW;
- $1,000 for structure and restraint systems;
- $2,000 for additional operating costs during the life of the car.

These make a total additional ownership cost of somewhere on the order of $5100.

Of course, that is not too much to save human lives but it would be unwise to spend that much money if there is another way in which the same money would save more lives. We believe such to be the case. Our cost-benefit studies show us that much of the excessive ESV costs come from the high-speed crash requirements of the specifications. Because real-world crashes at these high speeds are rare, the gain in occupant safety is limited despite the high cost of such protection (Slide 65).

ADDITIONAL RETAIL PRICES	
ACCIDENT AVOIDANCE (e.g. Lights, Anti Skid, Silent Copilot)	$1,100
RADAR WARNING DEVICE	$1,000
CRASHWORTHINESS (Structure, Restraint System)	$1,000
	$3,100
ADDITIONAL OPERATING COSTS (per Car Life)	$2,000
TOTAL	$5,100

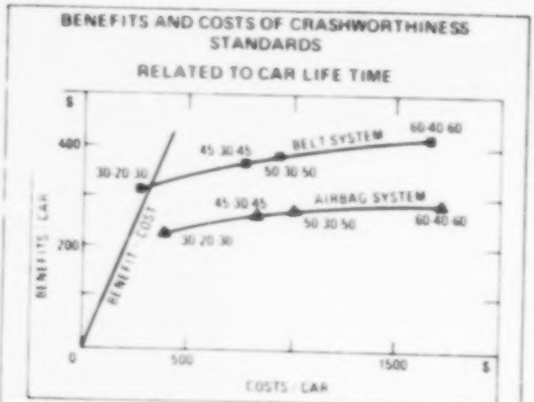
SLIDE 65

Shown on the next page are curves giving the costs and benefits of crashworthiness related to the life of the car. It would be more efficient, in our opinion, to increase the usage of belt systems by making active systems more comfortable and convenient, by making belt usage mandatory, or by passive belt systems. The cost-benefit of the belt system is greater than that of the air-bag system at all speeds. Indeed, the higher the speed, the wider the advantage of the belt system. ESV specifications call for a 50 mph frontal, 30 mph side impact and 50 mph rear impact. As can be seen from these two curves, the benefit flattens out as crash speeds increase. It is our opinion that for the higher speeds, greater benefits in safety will result from expending the same amount of money in other ways, including road construction, better lighting and signing, driver training and stricter vehicle and driver licensing requirements. Such actions by the governments would do more to reduce serious injury and fatalities at high speed than the same amount of money being spent to buy "super safe" cars such as the ESVW (Slide 66).

The international automobile industry has demonstrated its willingness to cooperate in important safety efforts such as the Experimental Safety Vehicle program. This willingness is amply demonstrated by the full commitment of resources and engineering talents that have produced the safety vehicles and systems exhibited at Transpo 72.

We, in industry, have learned a great deal from our work on the ESV program. We believe that our partners in this endeavor, the participating governments, have learned a great deal, too.

Now that the first phase of the ESV program has been completed, we believe that the participating governments will want to review the ESV specifications carefully in light of the actual results that have been attained. We hope that by reviewing the goals versus the achievements, new specifications will be written that will lead us toward safety vehicles and automotive developments with maximum public benefit per dollar spent (Slide 67).


BENEFITS AND COSTS OF CRASHWORTHINESS STANDARDS

RELATED TO CAR LIFE TIME

SLIDE 66

ESVW

SLIDE 67

INTERIOR SAFETY OF AUTOMOBILES – A STUDY OF THE GERMAN MOTOR INSURERS ON ROAD ACCIDENTS INVOLVING PASSENGER INJURIES

PROFESSOR DR. M. DANNER *Research Scientist*

German Association of Third Party,
Accident and Motor Traffic Insurers

In 1969 German Motor Insurers analyzed all their accident files involving injuries to persons owing to the permanent growth of road accidents and the increasing number of road deaths on the basis of motor vehicle third party liability insurance. The investigations of the Federation of Motor Insurers into "Accident Causation" and "Interior Safety of Automobiles" are based on this material. The "statistics of accident causation" included all serious and fatal injuries of all road users, namely injuries for which the persons were detained in hospital as in-patients, and had been analyzed with view to the cause of accident. The study on "Interior Safety of Automobiles" dealth with injuries of car passengers including slight and serious injuries as well as fatal injuries. With that study we thus obtained complete material about all sorts of injuries.

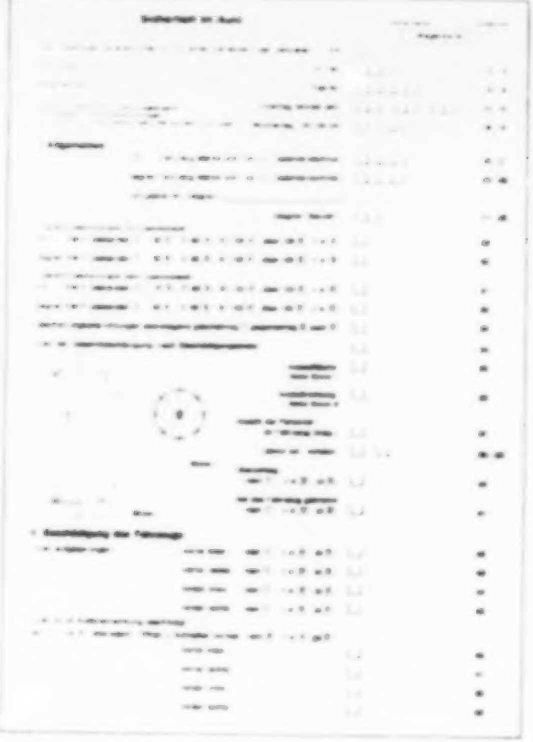
The material was exploited by means of the complete files of the individual insurers. 100 000 accidents had to be exploited in total. Since these cases were subjected to a thorough scientific analysis, only accidents containing precise particulars with respect to accident circumstances, damage to the vehicle and injuries sustained by the car passengers could be considered for further investigations. These exploitations are to be brought to a conclusion within short. We may then have about 30 000 accidents available which were exploited accurately. Since too much time would have elapsed until the conclusion of the final report, we already carried out a representative partial exploitation of 10 271 accidents. In 87 computer programs no less than 8 million data had been considered, and we already have obtained directive results and have been in the position to start with first investigations into the safety of vehicles which could still be refined considerably in the final report by means of the greater number of cases.

The exploitations had been carried out by our own group of experts of the Federation of Motor Insurers devoting themselves exclusively to this work. The examiners still gained far more additional experience by the plurality of the accidents dealt with whereby in some cases they also considered apparent trivialities which later proved to be the actual cause of some injuries. It turned out that only due to these our research techniques it was possible to investigate into an extremely great number of road accidents within a comparatively short period.

The leading idea for the recording of the data with view to the accident as well as the injuries sustained by the car occupants was to be as comprehensive, but on the other side also as compressed as possible. The data were registered in a statistical sheet containing in each case a vehicle card as well as a person card per injured occupant. The statistical sheet offers about 800 different possibilities of information with respect to the description of the accident and the damages to the vehicle alone, and the injuries sustained by the persons can exactly be described with about 500 different data. In order to achieve this, an extensive code had been elaborated the numerical entries of which only had been printed out on the statistical sheet in case they had appeared particularly often.

The exploitation of the accidents being dealt with is carried out by computers which are fed with conditions for certain accident groupings. Apart from the total sum of the cases in question we obtain as result a list on which all numerical information of such accidents are printed out, and in this manner we are able to draw any desired cross connection. Up to a dimension of 500 accidents particularly important investigations had been carried out with the additional handwritten notes and the photographs of the accident contained on the original statistical sheet.

directly taken from it. In the course of our investigations we could collect about 5,000 photographs for a photographic archive. This research method certainly requires an enormous energy; we do consider it, however, to be inevitable in order to come to clear and definite results which would largely exclude the danger of false interpretation.


Sicherheit im Auto

The collected and recorded data contain information groups, namely:

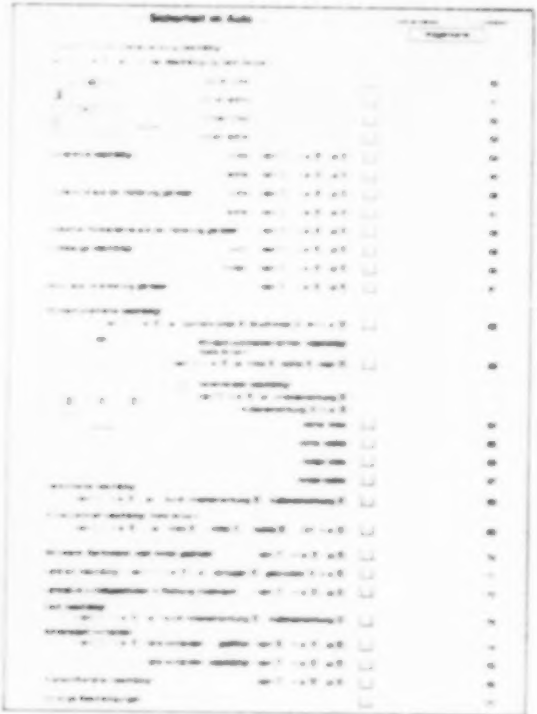
- Particulars about time and place of the accident
- Particulars about the cars involved in accidents
- Data on kind of collision and speed
- Particulars about damages to the vehicle

In order to pursue aimed-at research informations the respective accident vehicle must be known exactly. We have, therefore, noted down in our record: the manufacturer, model, year of construction and number of the chassis. The type of both the cars involved in accidents as well as their speed is of decisive influence for the energy of collision. When giving details with respect to the speed, we distinguished between the speed before the accident and the speed at the very moment of collision (reduced by using the brakes). Our experts ascertained these various speeds by investigating into the accident circumstances. The specification of direction with view to the center of gravity speed of both vehicles together with the surfaces of impact as well as the direction of impact give a clear picture of the relations of collision.

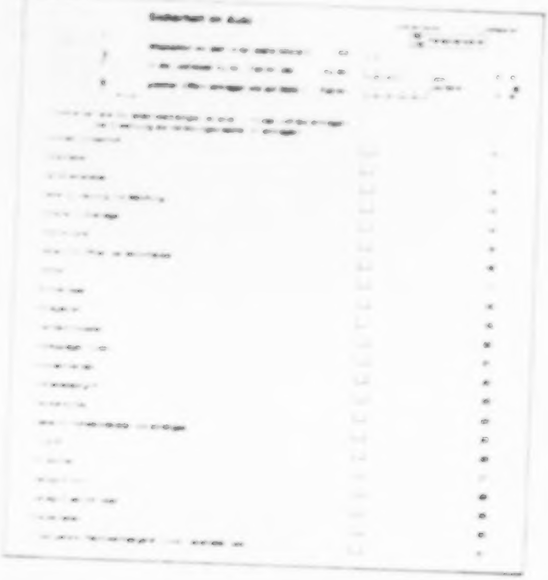
The degree of the damage sustained by the accident vehicle is characterized in five classes being classified as follows:

- *degree of damage 1* – slight deformation of non-bearing parts of the vehicle
- *degree of damage 2* – large-sized deformations of non-bearing parts with slight buckling of the frame
- *degree of damage 3* – medium damages to the frame with large-sized deformations of non-bearing parts
- *degree of damage 4* – considerable damage to the frame, the protective function of the passenger compartment being largely preserved
- *degree of damage 5* – most serious accidents, heavy deformations of the whole vehicle, the protective function of the passenger compartment being considerably reduced or having even completely ceased.

In addition to these number codings the kind and size of the damage to the vehicle are sketched by way of curtailed signs.


Sicherheit im Auto

The kind, position and severity of the damages to the parts of the car body are specified in further data. On this side the damages to the doors, front and back seats, engine, windscreen, side window, rear window, dashboard, front wall, steering wheel, top and fuel tank are recorded.



In contrast to these general damages, the damages to the particular parts such as a gear-shift lever, glove compartment, rear-view mirror, window crank etc. are indicated on the person card. The relation between an element of construction and the injuries sustained by an occupant resulting therefrom is thus ensured.

On this side of the person card particulars about the injured persons, whose seating position in the vehicle has been recorded anonymously, are taken down. The age, sex and seating position before and after the accident are entered — the throwing out of occupants being unfortunately still very frequent is recorded there. In the following it is recorded whether such injured persons had been protected by head-supports or safety-belts, and of which types these may have been.

The coding by numbers of the injuries sustained represent a special problem. The multiple injuries sustained by the occupants can only be assigned to a certain group with great difficulty, on the other hand would the general view be lost when forming too much subdivisions. We therefore have drawn up a novel type of coding system which proved a success in practice. Three informations characterizing the

severity, kind and place of the injury under consideration are given for each injured part of the body, such as head, chest, flank and the like. The classification of the severity of the injuries sustained correspond with the system as being used by the Cornell Aeronautical Laboratory. To obtain, however, additional possibilities of control and more exact information we took down in all cases the medical diagnosis in handwriting, mentioning the whole recovery process. By proceeding in that way we are able to pick out injury groups of the same kind by means of the numerical coding and to study them with view to their cause in connection with all the other injuries sustained by the occupant. It will thus be possible to exclude largely false evaluations.

It can be recorded under three further columns whether the occurrence of the accident was influenced by the active road safety of the accident vehicles, whether the passive safety was possibly impaired by any objects in the interior of the car, or whether any injuries were promoted by diseases. The recorded data are thus also supported by the handwritten notes, the calculations and photographs. Our investigations do therefore not only represent statistics in the usual sense but rather thorough technical analyses.

By means of the 30,000 accidents with their plurality of data being available when the studies will have been completed, we are in the position to investigate into nearly every question with view to the safety of vehicles. The following main points are shown by our further studies

- Description of the accident circumstances and the consequences resulting therefrom
- Investigations into particularly dangerous accidents, into the injuries and the parts of the vehicles having been damaged particularly often as a result of such accidents
- Influence of the vehicle construction in dependency on the kind of accident
- Investigations into the construction of the interior of the vehicle having promoted or prevented the occupants from being injured
- Investigations into the efficiency of the safety measures having been taken in case of the virtual accident

We are convinced – and this our conviction has been confirmed by our first investigations – that the efficiency of genuine safety measures can be demonstrated in a large-scale study on accidents in the everyday road traffic. The target of our future researches is not keyed to vehicle types but rather to their typical method of construction. For this reason we do hope that we will be able to produce fundamental results to the safety problems of passenger cars which will still be applicable when all the vehicles of our present time shall have already disappeared from the market.

INTERIOR SAFETY OF AUTOMOBILES

DR. KLAUS LANGWIEDER, *Engineer*

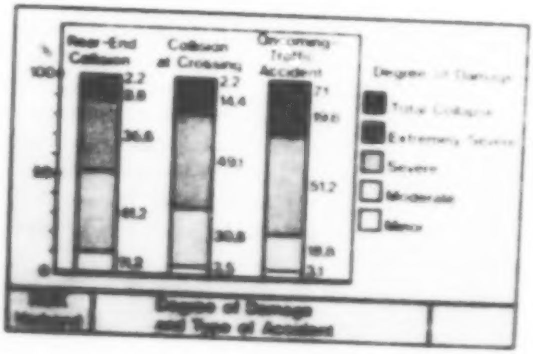
German Association of Third Party,
Accident and Motor Traffic Insurers

Main problems of car crash field studies

In order to be able to improve the safety of present day vehicles by specific measures it will be necessary to have an exact knowledge of the frequency of the various kinds of collision as well as of crash car strains and resulting injuries. It is one of the most important aspects of an investigation of road accidents having actually occurred to find a satisfactory answer to this question, thus providing data with respect to an order of precedence and extent of necessary safety measures.

Types of accidents and their resulting strains on cars

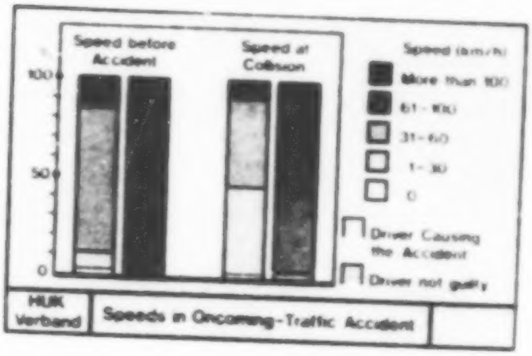
Among the so far evaluated 10,271 accidents with passenger injuries we have found that accidents at crossings dominate with 41.3%, followed by rear-end collisions with 30.2% and oncoming traffic accidents with 28.5%. The latter type of accident, however, shows by far the highest degree of damage, whereas in the case of rear-end collisions 52.4% of the vehicles hit from behind are only slightly to moderately damaged.



Degree of Damage and Type of Accident

According to the type of accident the vehicles are exposed to very different collision energies at the moment of collision. This fact is proved also by the comparison of the respective speeds.

Oncoming traffic accident

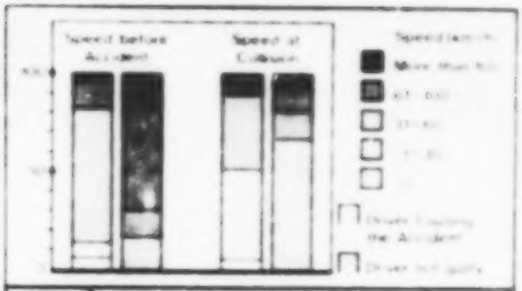


Speeds in Oncoming-Traffic Accident

Before the accident about 70% of all vehicles drive at a speed of close to 60 km/h. 24.4% of the persons causing an accident and 23% of the persons not guilty drive faster than 60 km/h, an indication of the balanced traffic situation. Due to braking the collision speeds of the vehicles are considerably lower. More than 90% of the vehicles collide in oncoming traffic accidents at a speed of less than 60 km/h. Of these, however, approximately 50% still drive at a speed between 30 and 60 km/h.

Rear-end collision type

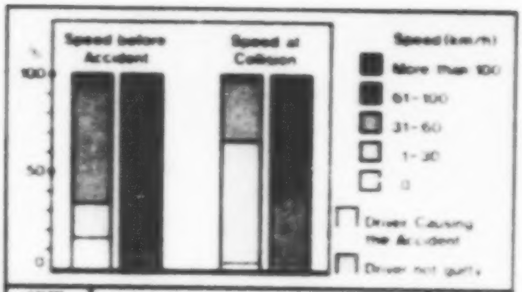
The driving speeds are lower than in the case of the oncoming traffic accident — an indication of the high share of accidents in city traffic. Before the collision only 16.6% of the vehicles hit from behind were standing, at the moment of collision, however, already 67.4% of the cars were standing. Hence it follows that rear-end collisions occur frequently at relatively low speed out of floating traffic. A relative speed difference of about 30 km/h exists in the majority of rear-end collisions.



HUK Verband — Speeds in Rear-End Collision

Those approximately 10% of vehicles causing a rear-end collision and driving at a collision speed of more than 60 km/h crash for the most part into cars which, also, are driving faster than 60 km/h.

Accidents at crossings



HUK Verband — Speeds in Accident at Crossings

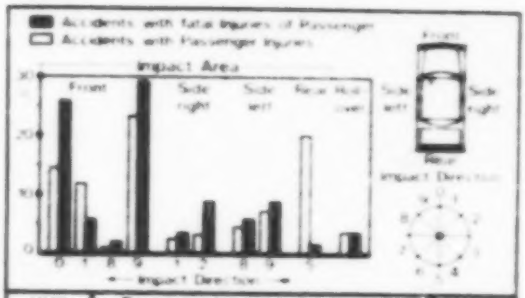
This type of accident happens above all in city traffic. For this reason 85% of the persons not guilty drive at a speed of less than 60 km/h. The right of way of the person not guilty had to be respected by the person causing the accident who, therefore, drives at a lower speed. Of these vehicles 16% were standing before the accident, at the moment of collision, however, only 2.3% were standing. From this follows that 12.7% of the persons causing an accident had started driving too early thereby either not noticing the vehicle having the right of way or under-estimating its speed.

In the very moment of collision 95% of all vehicles were driving at less than 60 km/h. The most frequent type of collision with respect to accidents at crossings is represented by a vehicle driving up to 60 km/h and entering into the side of a slowly running vehicle. In this connection it is especially unfortunate if the vehicle strikes in the door area since thereby the rigidity of the passenger cabin is reduced and a high portion of collision energy is transformed into car damage.

Passenger injuries in relation to the type of accident

In order to determine impacts that are highly dangerous for passengers we have compared the frequency of passenger injuries in general with fatal injuries in relation to the relative impact areas and directions on the vehicle of the person not guilty.

In the case of accidents with passenger injuries damage to front and rear parts of the vehicle is especially frequent. The left side is damaged almost twice as often as the right side.



HUK Verband — Passenger Injuries in Relation to the Type of Impact

The extremely frequent head-on collisions show a definitely increased risk of fatal injuries. To a lower degree this holds true also for both the left and the right side. Contrary to this the risk of fatal injuries in the case of rear-end collisions is relatively low. However, the latter type of accidents causes very often injuries of the cervical vertebra with a long recovery period.

According to our studies accidents with rollover of the vehicle which is often extremely damaged do not bear a risk of fatal injuries above average. This is due to the low deceleration during rollover, as long as the vehicle does not strike hard while rolling over. Due to opening of the doors and ejecting of the passengers dangerous injuries were four times, fatal injuries six times as frequent as in the cases of persons remaining in the car. Passengers who were protected by suitable restraint systems showed for the most part surprisingly slight injuries.

The frequency of accidents followed by fire is generally overestimated. In the so far fully evaluated material comprising 10,271 accidents a number of 22 accidents was contained whereby a vehicle had started to burn. Of all car accidents with passenger injuries these accidents represent only 0.2%. On the other hand this type of accident shows severe resulting injuries. The death rate of passengers arrives at 20%.

In order to be able to take suitable safety measures it will be necessary to know about the frequency of accidents whereby a heavy primary collision is followed by another collision with either a vehicle or object. We have noted such a "multiple impact" only when each one of the collisions could have caused passenger injury.

Accidents of this type have a share of 13.1% of all accidents with passenger injury and are not only very frequent but also show twice as heavy damage as normal. Efficient protection of passengers in the case of multiple impact can only be guaranteed by a safety system that will take effect also during an accident period of several seconds.

Frequency of damage in the interior

In almost one-fourth of the cases of accidents with passenger injury the windshield is damaged. In our studies tempered glass and laminated glass are represented according to their share in the market in Germany. Detailed investigations of the resulting injuries will be concluded in short. In one-fifth of all cases with shattered tempered glass splinters of broken glass remain in the lower part of the windshield thus representing an increased risk of heavy facial lacerations.

In 31% of our accidents the steering wheels were either bent or broken. Normally no serious injuries resulted therefrom.

Generally steering columns of present day vehicles are constructed so that they cannot be pushed into the interior of the car during the accident. Since our studies contained enough material with respect to models of older make we are in a position to examine the reduction of injuries by means of these measures at new models. A pushing into the interior of the car by a few centimeters has had no negative effect on injuries. Of decisive importance for the efficiency of a safety steering column is the yieldingness at the moment when the driver hits against. It is true that according to our studies concerning safety steering columns injuries of the thorax decrease. In the case of relatively small cars however there are some indications that head injuries increase due to the driver's head hitting the windshield.

In one-fourth of all accidents the dashboard is damaged whereby often moderate injuries occur. On the other hand we have found that especially serious injuries are often caused by dashboards which themselves were not damaged. It turned out that a noticeable effect can be obtained by an upholstering of a few centimeters.

Injuries of the passengers

In our studies we have broken down the risk of injuries according to kind and degree in relation to the position of the passengers in the car. In the general survey of injury risks with respect to different parts of the body the most frequent types of injuries in present day vehicles are shown. The risk of injuries varies definitely according to the position in the car. Especially, the very dangerous risk of head injuries (driver 39.6%, front seat passenger 51.3% of all passengers) and of injuries of the thorax (driver 17.2%, front seat passenger 14.8%) range well below the risk of injuries on the back seat. In the case of rear-end collisions two-thirds of all passengers showed cervical vertebra injuries.

Of all injured children more than 80% suffer head injuries. When the children are sitting in front add to these serious injuries of abdomen, upper thigh and leg.

A percentage of 5% of fractures of the cervical vertebra appears in the case of head-on collisions, of 3% in the case of rear-end collisions. 60% of these serious injuries occurred in connection with only moderate to rather severe damage of the vehicle. Eye injuries which according to the so far evaluated material were caused solely by tempered glass, even occurred in 50% of the cases in only moderate and in 30% of the cases in rather severe accidents. Consequently the majority of these serious injuries occurred in frequent and not too severe accidents.

Efficiency of safety measures

Direct comparisons between the same car models with or without special safety measures permits us to show a [illegible] with respect to their efficiency.

Concerning safety belts our material contained [illegible]

[illegible]

CONCLUSION

According to the type of accident different strains take effect in different areas of the vehicle. For this reason varying yieldingness is required for the different areas. The front area of a vehicle is to be constructed with utmost yieldingness. This will be of advantage also in the case of rear-end collisions and accidents at crossings. The door areas are to be constructed more rigid to the outside, with enough flexibility, however, to the inside. Since rear-end collisions occur for the most part with relatively low collision energy, car tests are to be adjusted accordingly. A higher degree of rigidity of the rear can also be compensated by a yieldingness of the front area the more as injuries in the case of rear-end collisions can be influenced favorably by means of suitable safety systems in the interior such as head restraints.

Simple restraint systems such as safety belts are to protect the passengers also in a collision lasting several seconds. Only by this means good protection can be guaranteed in the case of multiple impact or rollover of the vehicle. Moreover, they prevent an ejecting of the passengers due to the still frequent opening of the doors and render possible specific safety measures since the passengers are tied to their seats.

The majority of all accidents with passenger injuries occurs at speeds around or below 60 km/h. We have noted that also the majority of serious injuries is found at this speed level with moderate and rather severe car damage. The most effective influence on safety of cars is to be expected of measures which, at this speed level, either prevent or at least reduce danger of injuries considerably.

In this connection we have to try to reduce the risk of injury on both front seats by all means available since 89% of all passengers and 91.2% of all injured persons are sitting in front.

THE JAPANESE TECHNICAL PRESENTATION

SECTION 2 PART 6

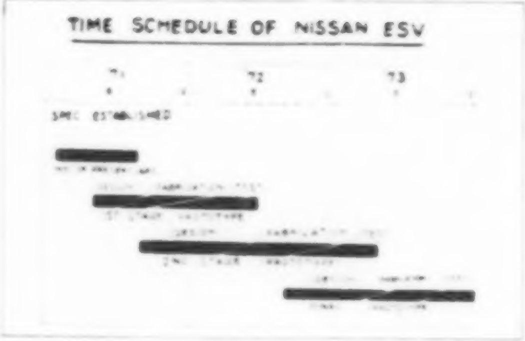
JAPAN

DR. RYOICH NAKAGAWA

Executive Managing Director
Nissan Motor Company

INTRODUCTION

Good morning gentlemen. As introduction to Nissan Motor Company's presentation, I would like to discuss our endeavors to achieve the goal of ultimate safety in motor vehicles manufactured by our company. Since the inception of Nissan's Experimental Safety Vehicle Program early last year, we have concentrated our efforts on the testing and evaluation of vehicles which are modified to comply with the ESV specifications. We have already modified from present vehicles more than one hundred vehicles, and most of them have been tested.

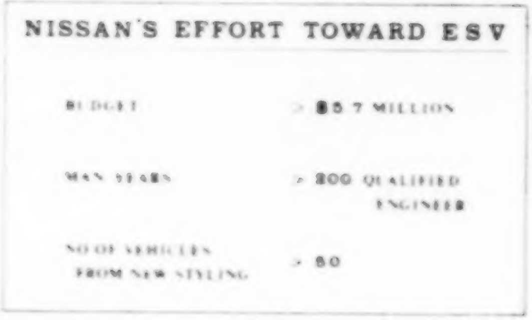


Having obtained useful results from these tests, we again evaluated the ESV specifications, and tried to plan our Nissan ESV from the standpoint of overall safety. Now we are designing the second stage prototypes, some of which will be shown here and at Transpo'72.

Unfortunately, we have not yet been able to achieve the desired occupant safety under the conditions of an 80 kilometer per hour head-on collision. However, we consider this to be a challengeable target and we hope to be able to integrate this safety feature into our ESV planning.

At the present time, our approach is rather practically based. Our Experimental Safety Vehicle policy, "a practical safety car for the next mass marketing" is, of course, in keeping with this approach. However, anticipating serious situations in matching ESV specifications from this approach, we are preparing another system and structure for better compliance. This modified ESV is rather sophisticated and more research-like. I will not mention this today.

A PRACTICAL SAFETY CAR
FOR
NEXT MASS MARKETING



NISSAN'S EFFORT TOWARD ESV

BUDGET	> $5.7 MILLION
MAN YEARS	> 200 QUALIFIED ENGINEER
NO. OF VEHICLES FROM NEW STYLING	> 50

By the end of 1973 we will submit our ESVs to the Japanese Government. Some variations of these models, including more research-like features, may be submitted at the same time. By that time Nissan will have spent more than 5.7 million dollars and will have utilized more than 200 man-years of qualified engineers on this project. We will build more than 50 vehicles originated from completely new styling. The goal of automobile safety and the implementation of this safety by automobile manufacturers more than possibly make heavy expenditures of time and money.

We at Nissan will earnestly do everything within our means to achieve this goal.

It is my great pleasure to present to you today some of our technical concepts in the field of auto safety.

I am very happy to introduce Nissan's speakers, Mr. Yoshio Serizawa, Manager of the Safety Research Department, and Mr. Tetuo Maeda, Manager of the Experimental Safety Vehicle Project in the Safety Research Department.

SMALL CAR SAFETY AND ESV SPECIFICATIONS

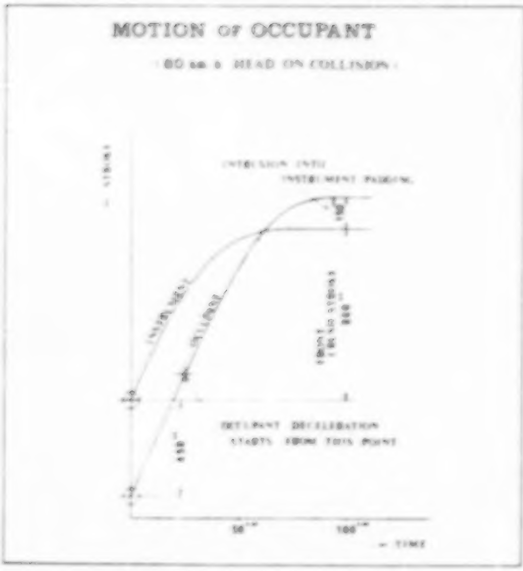
MR. YOSHIO SERIZAWA, *Manager, Safety Research Department*

Nissan Motor Company, Ltd.

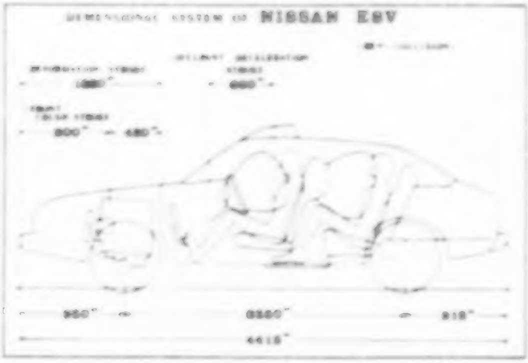
Thank you, Dr. Nakagawa. Good morning gentlemen. This morning I would like to discuss small car safety and ESV specifications. First, a few words about the general concept towards small car safety.

GENERAL CONCEPT TOWARDS SMALL CAR SAFETY

Nissan's Experimental Safety Vehicle is a small-sized passenger car, a four-door sedan which accommodates four passengers. "Small-sized" means small overall dimensions and light weight. Our first approach was to fix the vehicle dimensions to conform to the range of cars usually imported in the U.S., and also conform to the range of so-called "small cars" in Japan. Within this limitation we tried to determine dimensional systems which could possibly insure the survival of occupants under the ESV's test conditions.



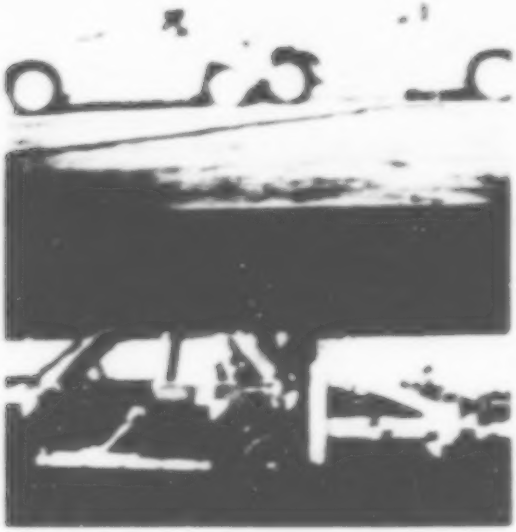
Crush stroke of the front body is 800 mm, which ensures an average of approximately 30 g in an 80 km/h barrier collision, and adding 150 mm's padding stroke, we will try to get a theoretical survival stroke. These dimensional systems do not have any redundance, but barely fall within the realm of theoretical possibility, thereby making them a worthwhile challenge. Therefore, we set the vehicle dimensions as shown on this slide.



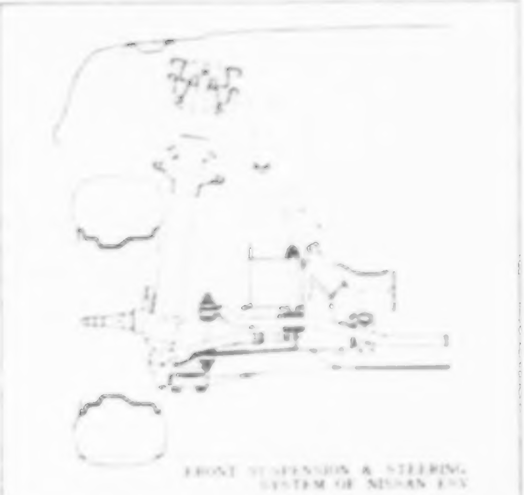
Concerning rear end collisions, we consider 80 kilometers per hour of a 4,000 pound moving barrier to be too severe, when compared with actual collisions caused by vehicles.

The slide shows the comparison of the "car-to-car" and the "moving barrier to car" rear end collision, having the same kinetic energy. It should be realized that the moving barrier substitution rather than the car-to-car collision is unacceptably severe. After careful investigation of this factor, we would like to propose that the speed of the moving barrier be changed from 80 kilometers per hour (50 mph) to 65 kilometers per hour (40 mph), or from a 4,000 pound moving barrier to a 2,500 pound moving barrier.

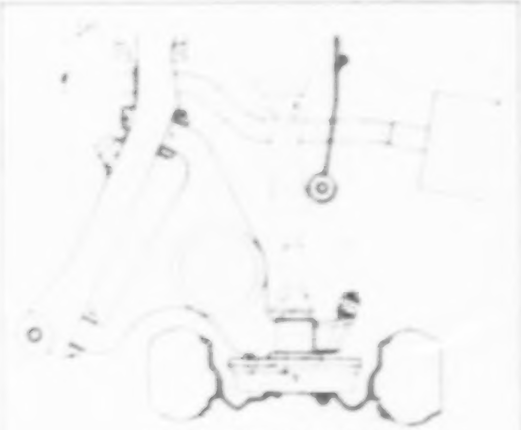
Concerning the realm of maneuverability, the small-sized vehicle has inherently superior accident avoidance characteristics. Endeavoring to develop



These characteristics were further than were specified ESV specifications, but it is a step towards the ideal solution of accident avoidance, which is a truly worldwide goal. We carefully analyzed the front and rear suspension systems and the steering system, and developed them. We also adopted and are developing a radar-braking system and a rearward visibility device as a prototype. The expense of these devices is not a factor if they contribute to safety without sacrificing practicability.

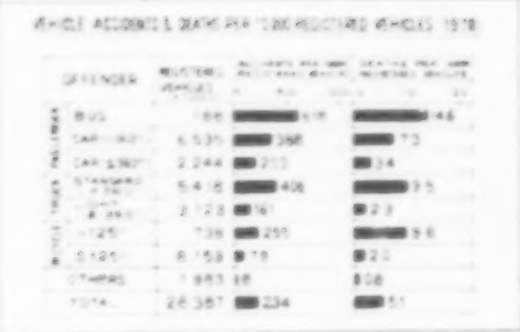


FRONT SUSPENSION & STEERING SYSTEM OF NISSAN ESV



REAR SUSPENSION OF NISSAN ESV

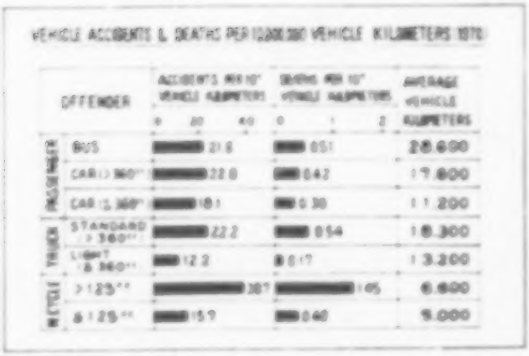
According to the annual traffic accident statistics recorded by the Japanese Police Department, we cannot conclude that a small vehicle is unsafe. This slide shows the number of accidents and the death rate per 10,000 registered vehicles.



VEHICLE ACCIDENTS & DEATHS PER 10,000 REGISTERED VEHICLES 1970

	OFFENDER	REGISTERED VEHICLES	ACCIDENTS PER 10,000 REGISTERED VEHICLES	DEATHS PER 10,000 REGISTERED VEHICLES
PASSENGER	BUS	188	618	46
	CAR (>360cc)	6,535	368	7.3
	CAR (≦360cc)	2,244	253	3.4
TRUCK	STANDARD (>360cc)	5,418	408	9.5
	LIGHT (≦360cc)	2,123	161	2.3
M-CYCLE	>125cc	738	290	9.6
	≦125cc	8,159	78	2.0
	OTHERS	1,983	18	0.8
	TOTAL	28,387	234	5.1

This figure shows that the small vehicles have less casualties, and the next slide shows the same rate of casualties per driving distance.



VEHICLE ACCIDENTS & DEATHS PER 10,000,000 VEHICLE KILOMETERS 1970

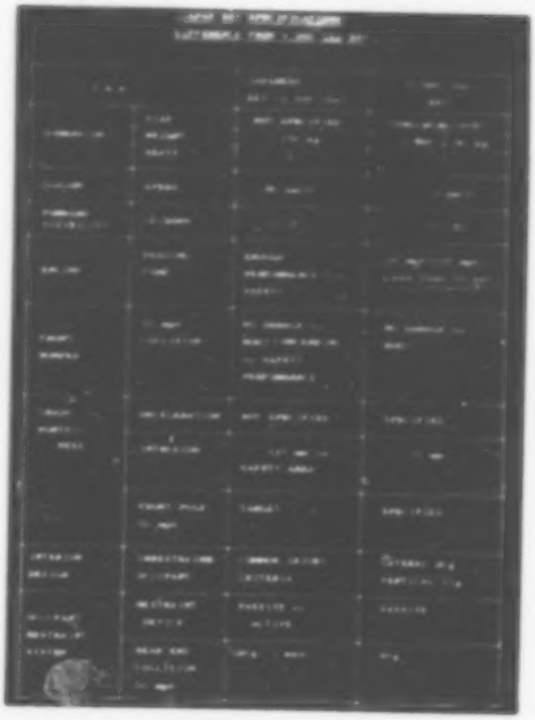
	OFFENDER	ACCIDENTS PER 10^7 VEHICLE KILOMETERS	DEATHS PER 10^7 VEHICLE KILOMETERS	AVERAGE VEHICLE KILOMETERS
PASSENGER	BUS	21.6	0.51	28,600
	CAR (>360cc)	22.0	0.42	17,800
	CAR (≦360cc)	18.1	0.30	11,200
TRUCK	STANDARD (>360cc)	22.2	0.54	18,300
	LIGHT (≦360cc)	12.2	0.17	13,200
M-CYCLE	>125cc	38.7	1.05	6,600
	≦125cc	15.7	0.40	5,000

As larger vehicles run for longer distances in the future all types of vehicles have almost the same rate of casualties, with the exception of motorcycles. The next slide also shows the same characteristics in spite of different uses.

Finally, I would like to speak about the evaluation and modification of ESV specifications.

EVALUATION AND MODIFICATIONS OF ESV SPECIFICATIONS

The main differences between the Japanese 2,500 pound ESV and the 4,000 pound ESV specifications are shown on this slide.



As you can see, with the Japanese 2,500 pound ESV, there are no specifications in body deceleration, passive restraint systems are optional, and front and rear pole collisions are only possible targets. Due to these differences, Japanese specifications are a little easier and more reasonable for auto manufacturers from an engineering standpoint.

Regarding head-on collision testing, we still consider 80 km/h as a possible target in our experiments.

However, as I mentioned earlier, rear-end collision testing will be conducted assuming a 4,000 pound moving barrier at a speed of 65 km/h (40 mph) rather than at a speed of 80 km/h (50 mph).

PROPOSAL FOR CHANGE
OF THE SPECIFICATIONS

INJURY CRITERIA

RESULTANT CHEST ACCELERATION

60 g → 60 g - 3 msec

REAR END CRASH TEST

TEST SPEED OF MOVING BARRIER

80 km/h → 65 km/h

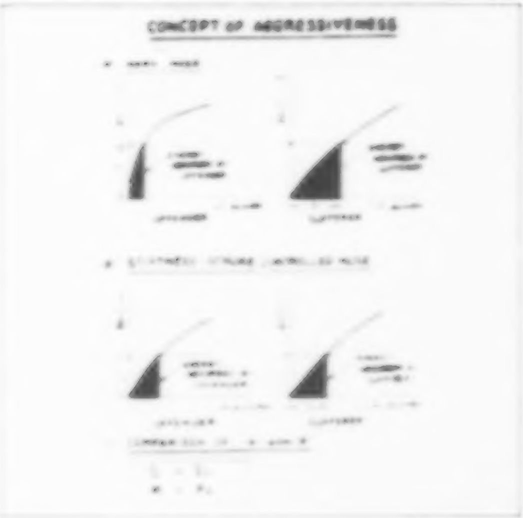
Considering the injury criteria, Japanese ESV specifications define occupants chest g's at less than 60 g, without any duration time. We would like to put 3 msec. as the duration time.

Regarding the injury criteria, there are many doubtful points. The Severity Index proposed in MVSS 208 will be more severe in an 80 km/h collision. We hope and suggest that the better injury criteria and dummy characteristics will be fixed by worldwide authorities.

We of course wish the damage to the sufferer hit by our ESV to be as slight as possible.

From the standpoint of the energy-managing characteristics of an 80 km/h head-on collision, a hard front structure against a soft structure of the sufferer is preferable, for the selfish purpose from the offender's standpoint. However, considering actual and rather minor accidents, and the better protection of the occupants in both vehicles, we will adopt optimal stiffness characteristics, in which the deceleration is increasing gradually in accordance with the collision speed and with the stroke increasing from the extreme front end to rearward.

Concerning the area of pedestrian safety, we are endeavoring to accomplish as much as possible within the practical limits of our safety vehicle, since in



Japan approximately one-third of the total traffic deaths are inflicted upon pedestrians.

This concludes my discussion of the general concept towards small car safety and ESV specifications. At this time I would like to present Mr. Maeda, Manager of the ESV Project at Nissan, who will discuss test results and Nissan ESV design.

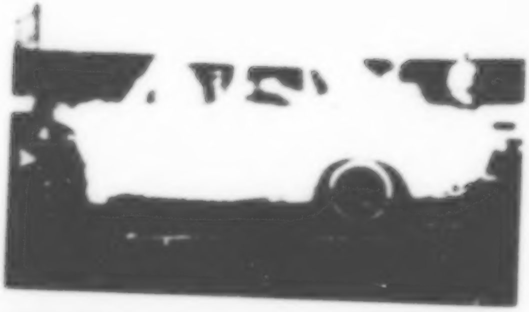
TEST RESULTS AND NISSAN ESV DESIGN

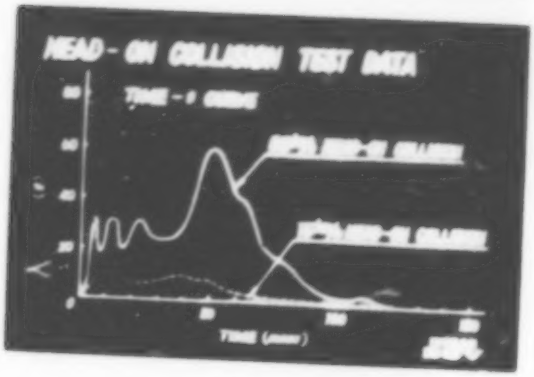
MR. TERUO MAEDA, *Manager, Safety Vehicle Project*
Nissan Motor Company, Ltd.

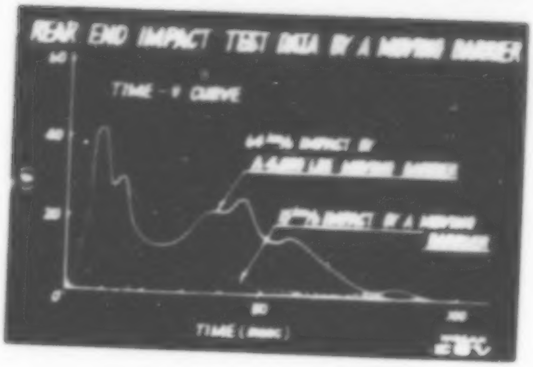
Thank you Mr. [illegible]. Good morning, gentlemen. This morning I would like to discuss test results and Nissan ESV design. First, a discussion of test results and their evaluations.

TEST RESULTS AND THEIR EVALUATIONS

Since August of last year, we have been experimenting with the first stage prototypes of the Nissan ESV. These prototypes have been and continue to be modified Datsuns extensively designed to satisfy ESV specifications.

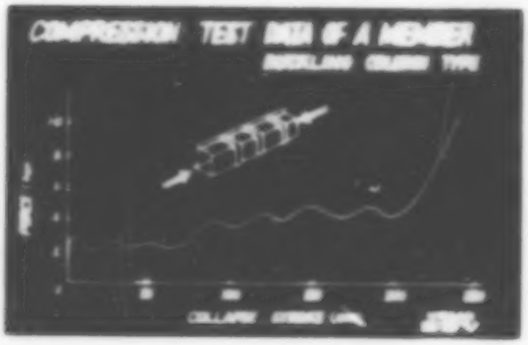


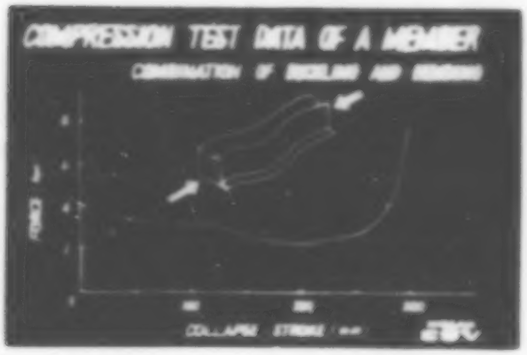




At this moment we are testing the last series of the first stage prototypes. The typical body g - t curve we are attaining is shown on this slide. We anticipate further improvement of the g - t curve to better accomodate the occupant protection system; however, now that the buckling column type crash mechanism of a practical monocoque body is confirmed, the fundamental shape of the curve will remain the same. Test data of the typical buckling column is shown on this slide.

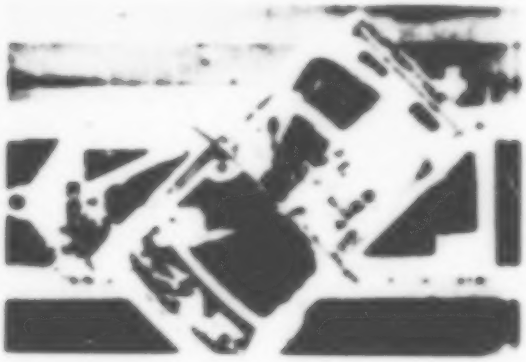
We at Nissan have also fabricated and tested a modified Datsun designed according to completely different concepts, such as a hydraulic damper

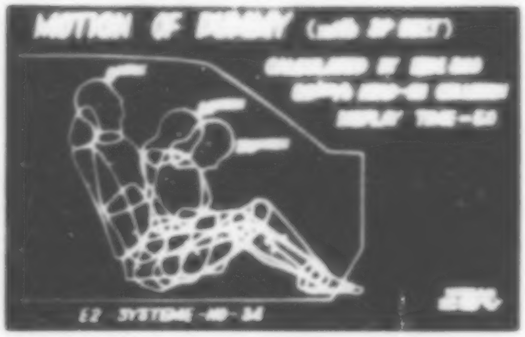




system, a sub-frame type structure system, and others.

Concerning the subject of occupant protection, we have been conducting "cart test." The "cart" mounts the occupant protection system, and its deceleration is controlled by energy-absorbing materials fitted in front of a barrier. We have been and will continue to explore every suitable type of occupant protection system, taking into consideration the many kinds of air bags, crash and radar sensors, seat belts, safety seats, paddings, and other devices which have been developed.





We have [illegible] to satisfy the ESV requirements and [illegible] behavior of the [illegible] of the [illegible].

At this time, I would like to show you a [illegible] vehicle with [illegible] to [illegible] Nissan [illegible] to satisfy the ESV requirements.

MOVIE EXPLANATION

Development of Nissan ESV

At this time, I would like to explain the [illegible]. The [illegible] of the [illegible] passengers.

Breaking Performance

The vehicle stops in about 43 m from 96 km/h without any side skidding. We equipped front disc brakes with a power assistance and an antilock device to the rear wheels.

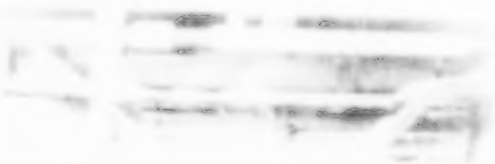
The Slalom Test

This is one of our strongest areas. The vehicle can be driven at 80 km/h through pylons spaced at 30 m, and proves the excellent ability of accident avoidance.

The J Turn

The [illegible] is controlled. The [illegible] at the speed [illegible] km/h and the ESV requirements [illegible].

Static Collapse of the Body Structure



To develop the crashworthiness, we have conducted many kinds of static collapse tests. The front structure is being pressed.

The body side is collapsed by a pole. We are obtaining a correlation between static and dynamic behavior.

Scale Model Tests

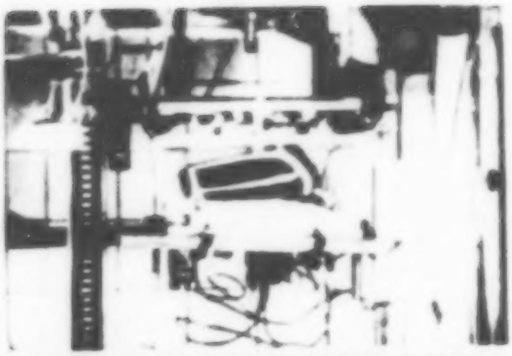
We have been conducting scale model tests for body structural analysis. A scale model of the rear floor

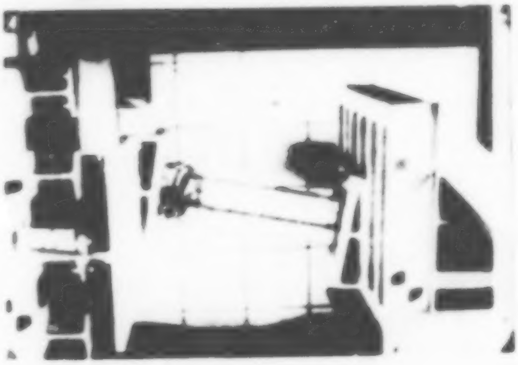
A dynamic test of the rear end structure model. To attain a correlation, the test of full-scale model of the rear end is conducted.

Crush Behavior of Other Component Units

The tests of component units which are thought to have great effects on crash dynamics are conducted.

The heavy seat.
The periscope.
The fuel tank on Hy-Ge.
A head form tester.
The Urethane padding hit by the head form.
The honeycomb material hit by the head form.
The engine mounting test on a Hy-Ge.





Dummy Response Tests

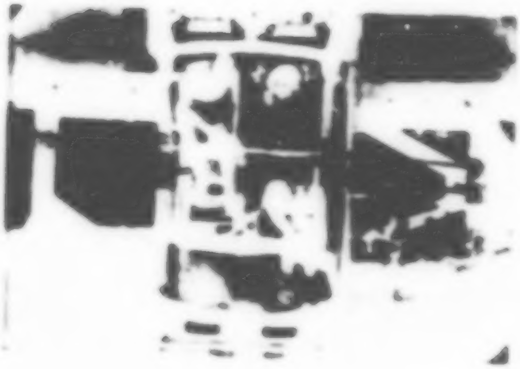
Static response of a dummy is measured.
By means of a hammering test, dynamic response of a dummy is calculated.

A Sled Test Simulating a Rear End Collision

Occupant protection systems are developed at first by a sled test.
A 50 km/h, 45 degree angular collision of rear end is simulated.

A Sled Test Simulating a Side Collision

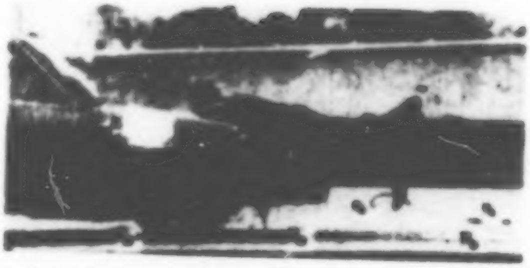
A 25 km/h fixed pole impact is simulated.



A Cart Test Simulating a Head-on Collision of 80 km/h

A cart mounts the body compartment with the occupant protection system. The decleration of the cart is controlled by lead tubes fitted on the front of a barrier and is in this case a square wave of 30 g. A combination of air bags and lap belts comes close to reaching the injury criteria.

Pedestrian Safety

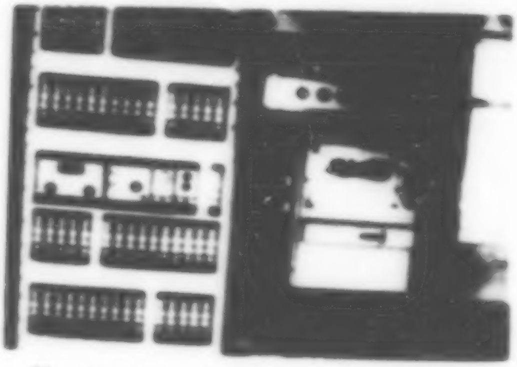


A current model Datsun 510 hits a pedestrian. His head collides with the vehicle body and the peak g kills him.

The long hood accomodated the energy absorbing materials like honeycombs. The speed is 15 km/h.

By installing the pedestrian control bar, the trajectory of the pedestrian is somewhat controlled. The speed is 32 km/h.

Data Processing System



The data attained from a vehicle crash test is recorded through these instrumentations and will be calculated by computers. Seventy channels can be recorded simultaneously.

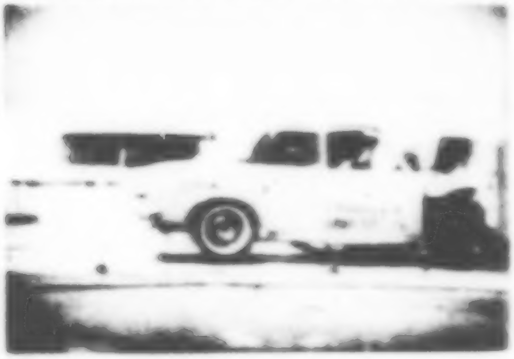
An 80 km/h Head-on Collision of a Current Model Datsun 510

Back to a base line test done before. A current model Datsun 510 was tested. The energy of 80 km/h couldn't be managed by the vehicle body. The survival space was not found and four dummies were dead. This was the very start of our long ESV program.

An 80 km/h Head-on Collision of a Bending Frame Type Vehicle

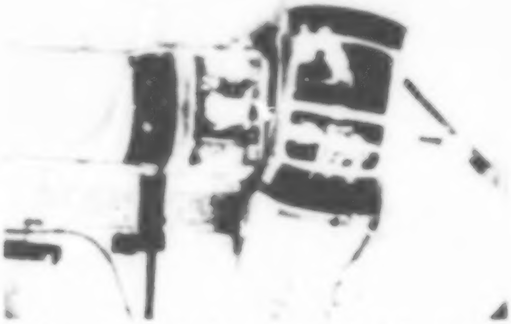
As one of the variations among the first stage prototypes, we designed a subframe type vehicle. The energy of 80 km/h is intended to be managed by bending the frames.

An 80 km/h Head-on Collision of the Last Series



Preinflated air bags and lap belts are equipped for both front and rear seats. The energy of 80 km/h is not precisely controlled and the body deformation around the cowl top is not small enough. The four dummies are not still alive.

A 50 km/h Car-to-Car Side Collision



The vehicle is hit by a vehicle which has the same front end characteristics as our ESV. Although the maximum deformation of the inner surface is around 150 mm, the survival space seems to remain and the injury criteria are almost satisfied.

A Drop Test

The vehicle with a periscope is dropped from a height of 600 mm. The deformation looks large, but putting dummies in the compartment, we proved that the survival space is satisfactory.

A Rear End Collision of a Vehicle with a Hydraulic Damper

As another variation, we tested a vehicle with a hydraulic damper. The energy of a 1,800 kg, 80 km/h moving barrier is mostly managed by the large hydraulic dampers.

The units of the same type are also installed to the front.

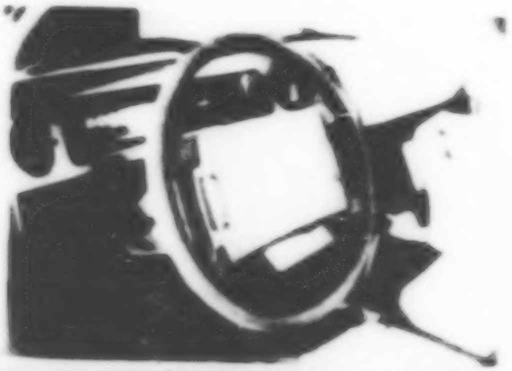
A Rear End Collision of the Last Series

An 1,800 kg, 65 km/h moving barrier cannot take away the survival space. The injury criteria of the

deformations are almost satisfactory. No fuel leakage is found.

The Nissan ESV Prototype

This is our ESV, the small-sized practical safety vehicle. Having obtained extremely useful information through testing the first stage prototypes as just mentioned, we will build the second stage prototypes with this styling. The tests and evaluations of these second stage prototypes will commence this autumn. We presume that valuable feedbacks from them will enable the last stage prototypes. We hope these prototypes, when submitted to the government, will be more satisfactory and reliable.

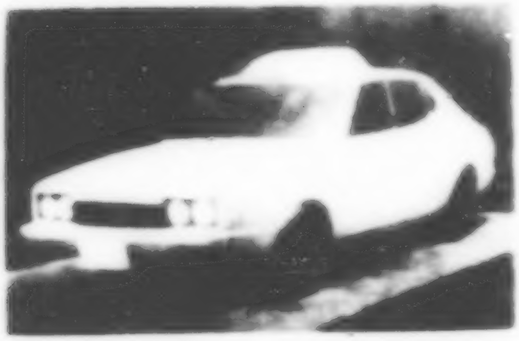


Finally, I would like to discuss the general aspects of Nissan's ESV.

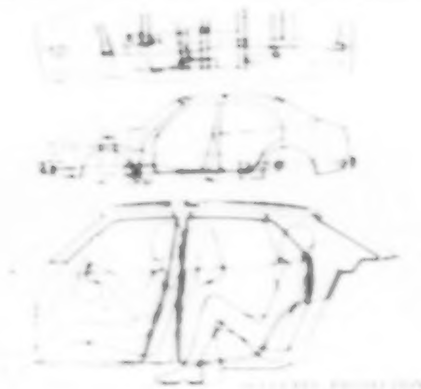
GENERAL ASPECTS OF NISSAN'S ESV

The testing and evaluation program of the second stage prototypes of Nissan's ESV, incorporating a completely new style, will commence this autumn.

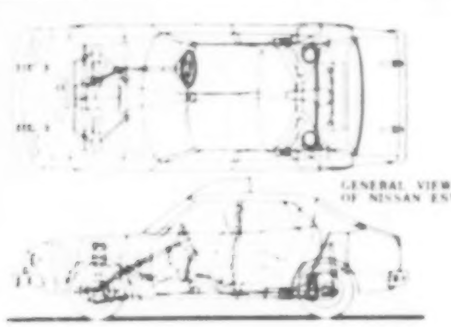
The general concepts of this vehicle originated from a small-sized, practical passenger car, incorporating easy handling characteristics. We didn't want to sacrifice any features which add to the practicality of these small-sized vehicles. The main dimensions and specifications are shown on this slide.



MAIN SPECIFICATIONS OF NISSAN ESV



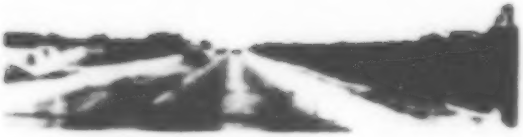
OCCUPANT PROTECTION SYSTEM OF NISSAN ESV

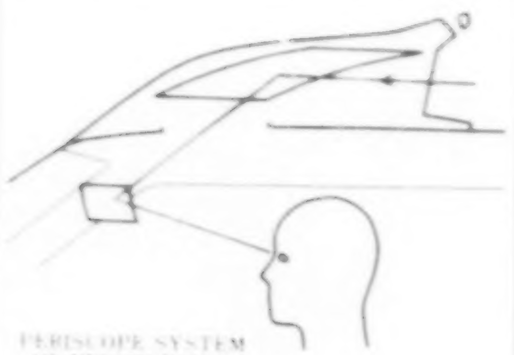


GENERAL VIEW OF NISSAN ESV

The bumpers are mounted by hydraulic dampers and absorb the energy of a 15 kilometer per hour head-on collision. To attain the survival possibility of a pedestrian hit by the vehicle, urethane coating of the bumper surface, lower nose of the front end, and energy management of the hood have been considered.

Very bright head lamps controlled by a speed sensor have been installed. A large periscope, providing rear vision nearly three times as wide as an





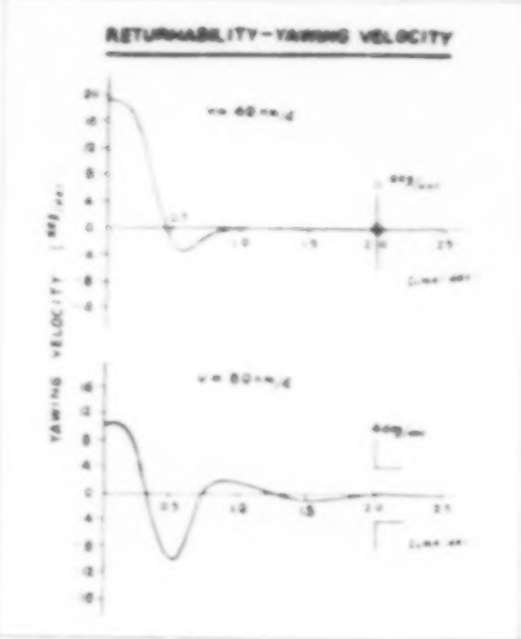
PERISCOPE SYSTEM
OF NISSAN ESV

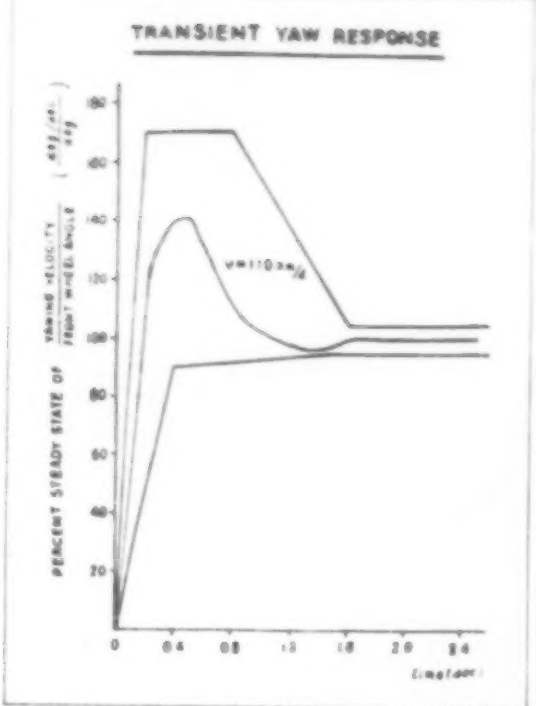
ordinary car has been installed. This device is equipped with a special feature to prevent the accumulation of rain and dust. The combination of curved mirrors enables us to lower the overall height of the periscope, which contributes to the vehicle's styling. The problems which still remain are distortion of vision and limitation of acceptable eye range. Regarding their solution, the former depends on preciseness of the mirror processing and the cost. The latter depends on the size of the mirrors, i.e., the height of the periscope.

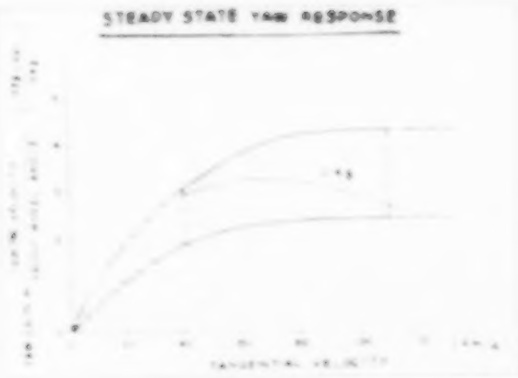
The combination of a strut type front suspension and a rack and pinion steering unit provide adequate system rigidity. A semi-trailing type independent rear suspension gives the vehicle not only a fine attitude control which surpasses the requirement, but also excellent road holding and ride comfort.

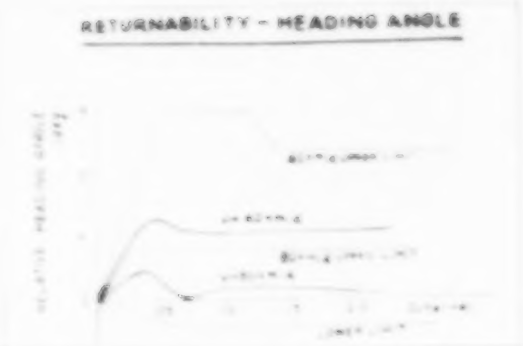
HANDLING AND OVERTURNING IMMUNITY

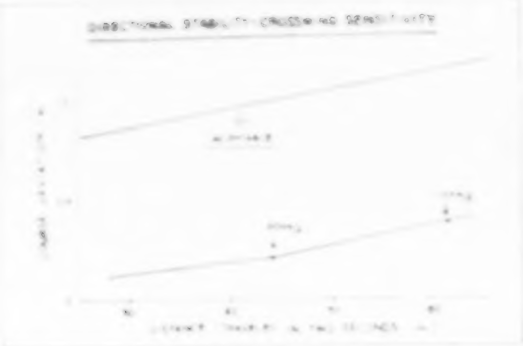
ITEMS	JAPAN ESV SPEC	NISSAN ESV
HANDLING		
LATERAL ACCELERATIONS	≥0.60g (DRIVER CONTROL)	0.72g
CONTROL AT BREAKAWAY	≤4.0sec (COURSE RECOVERY)	2.8 sec
DIRECTIONAL STABILITY		
PAVEMENT IRREGULARITY SENSITIVITY	≤30cm (COURSE DEVIATION)	17cm
STEERING CONTROL SENSITIVITY	≤53kg-cm (STEER TORQUE)	8.8kg-cm
OVERTURNING IMMUNITY		
J-TURN	500 deg/sec, 180deg, 110 km/h	OK
PYLON COURSE	80 km/h (30m INTERVALS)	OK

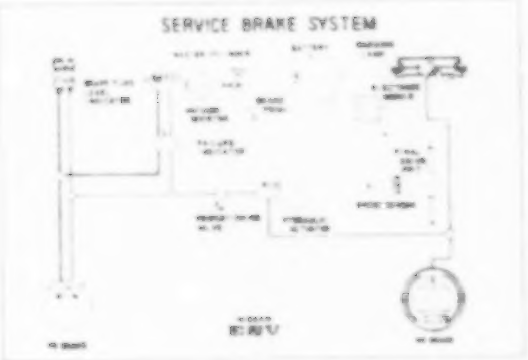




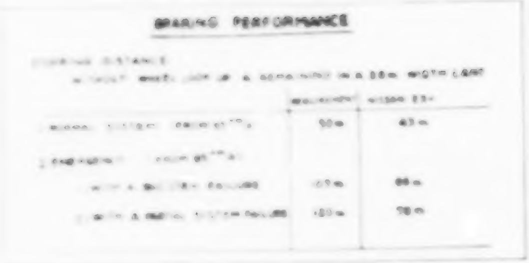








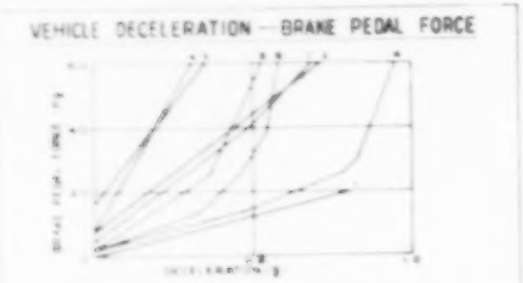
[illegible] [illegible] with high lateral stiffness and a high [illegible] [illegible] enable the vehicle to be driven [illegible] [illegible] after the occurrence of a tire puncture. Power-assisted disc brakes with antiskid devices [illegible] performance which satisfies ESV requirements.



BRAKING PERFORMANCE

STOPPING DISTANCE
WITHOUT WHEEL LOCK UP & REMAINING IN A 3.6m WIDTH LANE

	REQUIREMENT	NISSAN ESV
1. NORMAL SYSTEM (FROM 60 MPH)	50 m	43 m
2. EMERGENCY (FROM 60 MPH)		
a. WITH A BOOSTER FAILURE	107 m	88 m
b. WITH A PARTIAL SYSTEM FAILURE	120 m	78 m

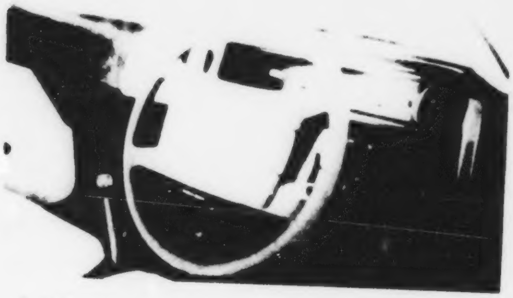


	REQUIREMENT	TEST DATA
NORMAL	BETWEEN LINES [illegible]	A
PARTIAL SYSTEM FAILURE	BETWEEN LINES [illegible]	B
BOOSTER FAILURE	BETWEEN LINES [illegible]	C

We intend to incorporate an effective communication system for trailing vehicles. This system will include highly mounted turn signals and two levels of lamps in addition to road lamps mounted on the rear of the vehicle.

The brightness and the locations of these lamps have been carefully selected by visual testing under every kind of circumstances, such as day and night driving, weather conditions, many situations of rela-

tive movement between travelling vehicles, and others.



Inside the vehicle, a legible speedometer and central warning indicator are in front of the driver. Extensive care was taken to provide a soft, relaxed atmosphere which will hopefully reduce accident-causing excitement. Additional highlights of the vehicle include neatly-designed safety seats and paddings. As is shown on these slides, the "seat belt" type of occupant restraint system is incorporated in this vehicle.

This concludes my discussion of Nissan's test results and ESV design. At this time Dr. Nakagawa will make Nissan Motor Company's concluding remarks.

CONCLUDING REMARKS

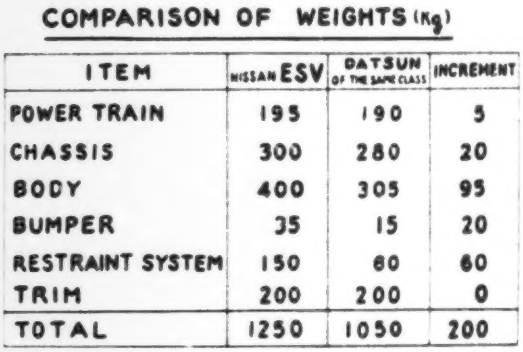
DR. RYOICH NAKAGAWA, *Executive Managing Director*

Nissan Motor Company, Ltd.

Thank you, Mr. Maeda. Nissan Motor Company's ESV is progressing generally on schedule, although there have been and will continue to be some delays due to requirement difficulties.

Needless to say, the requirements for crashworthiness and occupant protection for the small-sized vehicle are extremely hard to satisfy. These points were explained earlier.

We at Nissan will continue to develop our ESV from the standpoint of practicability in addition to satisfying the ESV safety requirements. The following are some of the problems which we hope to solve in the near future:



COMPARISON OF WEIGHTS (Kg)

ITEM	NISSAN ESV	DATSUN OF THE SAME CLASS	INCREMENT
POWER TRAIN	195	190	5
CHASSIS	300	280	20
BODY	400	305	95
BUMPER	35	15	20
RESTRAINT SYSTEM	150	60	60
TRIM	200	200	0
TOTAL	1250	1050	200

1. Weight: We hope to apply a quantity of light alloys, high tensile steels, and plastics to our ESV in the near future. Nevertheless, the problem of weight does not seem to be one that can be easily solved.

   Increments of the weight from a current vehicle of the same size are shown on this slide.

2. Roominess: Occupant safety devices inhibit passenger space, especially in the rear seat area. The passenger in the rear seat might be very depressed. A comprehensive solution to this problem is urgently needed.

3. Direct Visibility: It has not yet been conclusively determined whether indirect visibility, similar to that of a periscope, would be more practical than direct visibility.

We at Nissan are very proud of our efforts to develop an Experimental Safety Vehicle as a total safety system, and we are determined to do our best to attain this worthwhile goal in the interest of the welfare and happiness of mankind.

OUTLINE OF TOYOTA ESV PROGRAM

MR. TATSUO HASEGAWA, ***Director***

Toyota Motor Co., Ltd.

Toyota Motor Company has been endeavoring to make technological progress in the field of vehicle safety, and we have made up our minds to build a Toyota ESV prototype in cooperation with the ESV project of the U.S. Department of Transportation and the Japanese Government.

In June, 1971, answering the request of the Japanese Government to build an ESV, Toyota applied for the 2-seater sedan with a weight of 900 kg and has been making strenuous efforts for its development since that time.

We have not only about 30 staff engineers fully engaged in designing our ESV, but also many other members who are partially engaged in the various facets of its development.

By the end of 1971, our efforts were mainly directed to confirming our concepts and to modifying the present car structure in order to improve its crashworthiness. At the same time, we started a study of the subsystems which are to be incorporated into the ESV, for example, the bumper subsystems, occupant restraint devices, brake systems and warning systems.

Because of this initial study, we finished the basic survey of the Toyota ESV at the end of last year and have been engaged in detail concerned with the design of the ESV since February of this year.

Following is the Toyota ESV development schedule:

We have a plan to build 60 prototype units in all, from now on: 20 first prototypes – from June to September of this year; 20 secondary prototypes – by the end of next February; 20 final prototypes – by the end of September, next year. We will deliver ten final prototypes to the Japanese Government by the end of 1973.

In this Transpo 72, we are exhibiting a full scale plastic model of the first prototype.

Now, I would like to explain to you some of our purposes in designing our ESV. Crashworthiness is emphasized as our most important target. However, I have to confess that at phase zero, we had no concept of how to meet the ESV specifications, including the 80 km/h frontal collision. Therefore, we established the following two basic policies for the ESV project:

1. With respect to crashworthiness, we will work forward to attain the current ESV specifications.
2. As for the accident avoidance specifications, we will do our best with our present available technology.

We think it is very difficult, but necessary, in today's mixed traffic, to give the same crashworthiness to smaller cars as to the full-sized cars.

The reason why we chose a 2-seater small sedan is that it seems to us, under the present state-of-the-art, we have the best technical feasibility of meeting the ESV specifications of smaller cars which must be compatible to that of full-sized cars in the current mixed traffic situation.

Let me add a few more words in conclusion about our objectives and problems in the Toyota ESV program.

When we review the development situation of our program, I might say that we will be able to meet the specifications of the ESV in the end. But we still have problems in weight and economy. Based upon our current estimates, it will be inevitable that the final weight will be 250 kg above the original goal. As an automobile manufacturer, we should study more how such weight and economy could be harmonized into the safety features.

Now, I would like to turn the floor over to Mr. Jiro Kawano, Chief Designer of our ESV, who will explain to you more in detail the Toyota ESV first prototype, and will show you the process of development.

Thank you very much for your attention.

OUTLINE OF FIRST PROTOTYPE AND EXPERIMENTAL STUDY

MR. JIRO KAWANO, *Manager, ESV Chief Designer*

Toyota Motor Company, Ltd.

GENERAL SPECIFICATION

The prototype, which I would like to explain today, is a 2-seater sedan. As figure 1 indicates, it has total loaded height of 1.36 m, overall width of 1.8 m, overall length of 4.3 m, wheelbase of 2.3 m and 1.5 m tread both in the front and in the rear.

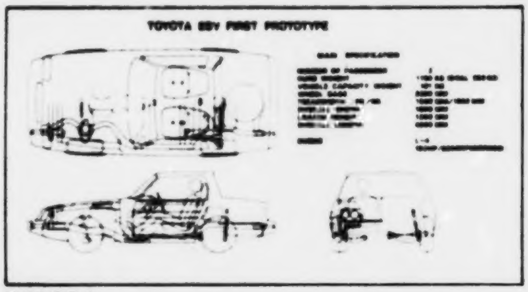


FIGURE 1

The specified curbweight is 900 kg, but the actual curbweight is supposed to be approximately 1,150 kg based on our current design estimates.

As figures 2 and 3 show, the car was designed as a 2-seater touring sedan. In order to meet the ESV specifications, the design of this car tended to have some unique appearance.

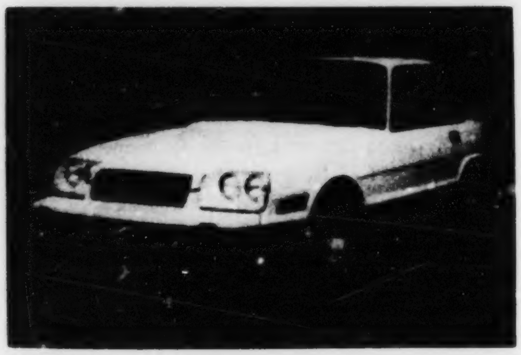


FIGURE 2

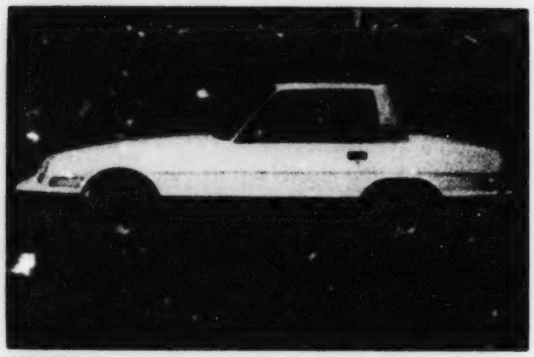


FIGURE 3

BRAKE SYSTEM

For service brakes we have a dual brake line system. It has disc brakes with dual piston caliper in the front and disc brakes with single piston caliper in the rear, and has a tandem master cylinder with a booster. The anti-skid device is composed of the actuators and a speed sensor at each wheel. Figure 4 shows the service brake system.

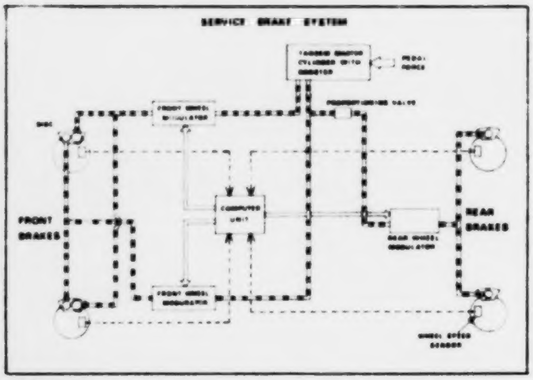


FIGURE 4

Figure 5 shows the theoretical performance of the brake, and we expect that we can meet the requirement. We also have warning systems of partial pressure line system failure, skid control system failure, power assist failure, a[illegible]lso warning system failure.

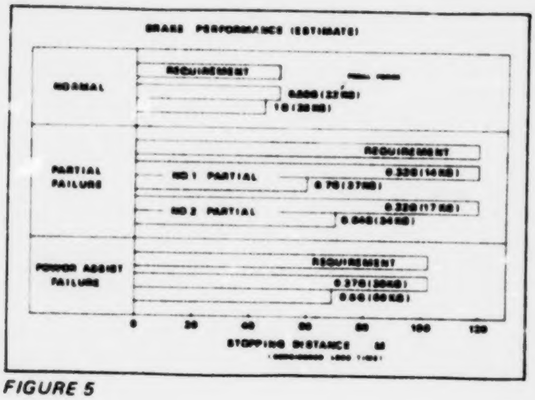


FIGURE 5

STEERING AND SUSPENSION SYSTEM

For steering mechanism, we have a rack and pinion gear box, a steering shaft with two joints, a collapsible steering column and a steering wheel which contains a gas bag.

For suspension mechanism, we have double wishbone type one in the front and semi-trailing type one in the rear. We can mount the tire up to DR60-14 and 6" width rim.

LIGHTING SYSTEM

It has four units of headlamp lights with four modes of beam operation, as shown in figure 6, and the maximum illumination is 120,000 beam candle power. Besides headlamp covers with electric heater are installed for the cold weather.

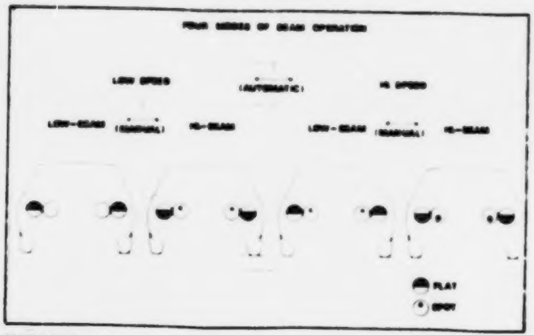


FIGURE 6

Figure 7 shows the rear lighting system. Brake lamps are red and the brightness can be changed in accordance with the circumstances. For driving lamps, we are going to study the feature of green color. Important lamps have the bulb failure warning systems and the functions of redundance.

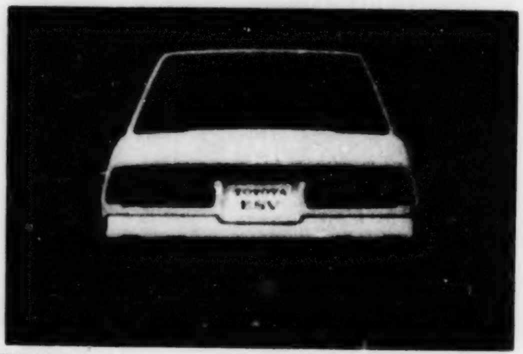


FIGURE 7

VISIBILITY

The forward visibility through the windshield is 17° of upward angle and 6° of downward angle, which meets the ESV specification.

A large rear view interior mirror enabled us to have wide rear vision of 45°. Figure 8 shows the field of view.

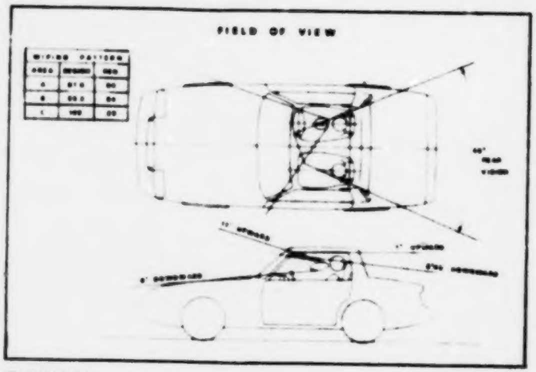


FIGURE 8

INSTRUMENT AND DRIVER'S CONTROL SYSTEM

The interior design is carried on giving priority to the occupant protection, while the driver's controls are arranged to lighten his burden from the standpoint of accident avoidance. Figure 9 shows the view.

The instrument panel has crushable construction and the surface is wrapped up by a soft pad. The combination meter in front of the driver is simply composed of a speedometer, a fuel gauge and a master failure warning signal as shown in figure 10, to give the minimum information necessary for the driver.

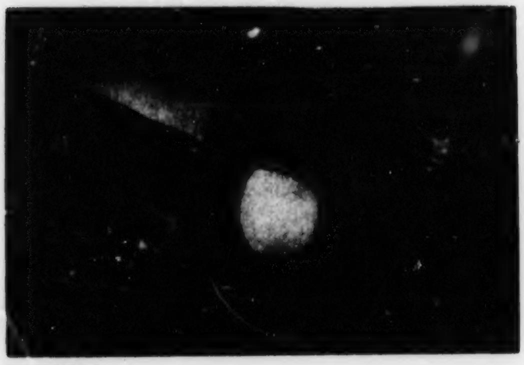


FIGURE 9

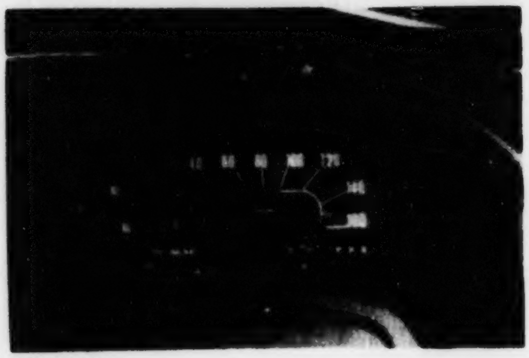


FIGURE 10

For the purpose of reducing the crash injury and avoiding the unsafe situation caused by troublesome operation, the driver controls are removed from the front impact zone. The controls which have to be operated frequently are located on both sides of the steering column and the rest of them are arranged in the center console according to their functions, as shown in figure 11.

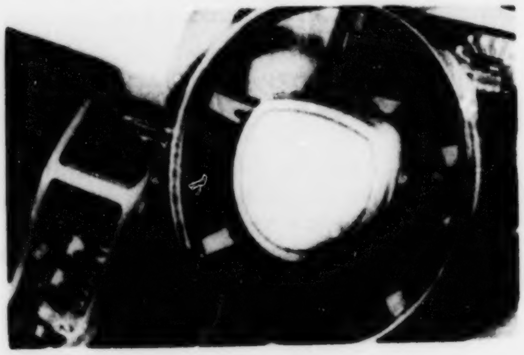


FIGURE 11

The malfunction analyzer shown in figure 12 is equipped on the center console. When one of the sensors sends a failure signal, the master failure warning signal in the combination meter is actuated in proportion to the degree of the failure. Then, by looking at the malfunction analyzer board, the driver can recognize the exact information of the failure.

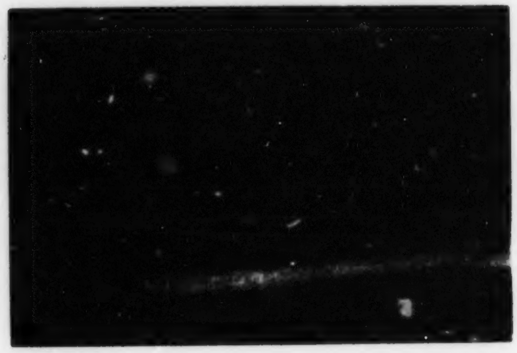


FIGURE 12

In addition, a single wire multiplex network system is adopted to deal with a lot of information. Sub-computers located in the engine compartment, dash panel, console, etc., are linked by a few wires and talk to each other by signal.

The form of the signal is serial pulse code modulation, and pulses travel to sub-computers, but affect only those listening during the same interval. This system could reduce wiring harness complexity which causes the harness dead-short and firing. Figure 13 shows the concept of this system.

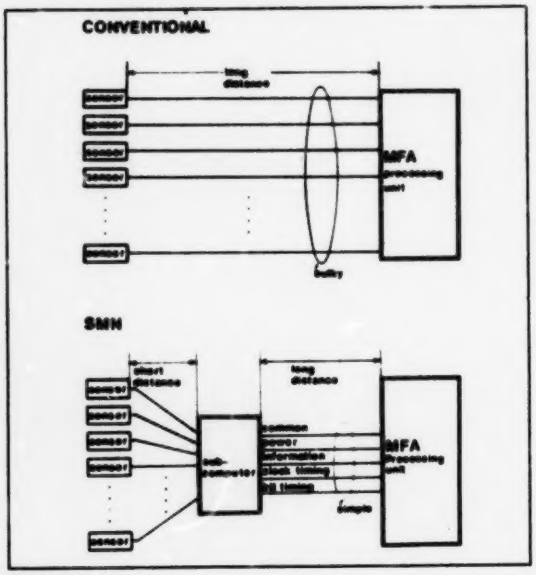

CONVENTIONAL
long distance
sensor
sensor
sensor
sensor
sensor
MFA processing unit
bulky
SMN
short distance
long distance
sensor
sensor
sensor
sensor
sensor
sub-computer
common
power
information
clock timing
simple
MFA processing unit

FIGURE 13

The seat is a high-back chair type, and is adjusted by conventional back and fore adjustment.

For the occupant protection in case of side collision, an energy absorbing separator board is located in between both seats, and crushable energy absorbing door trims are also furnished on the door inside panels. Figure 14 shows this layout.

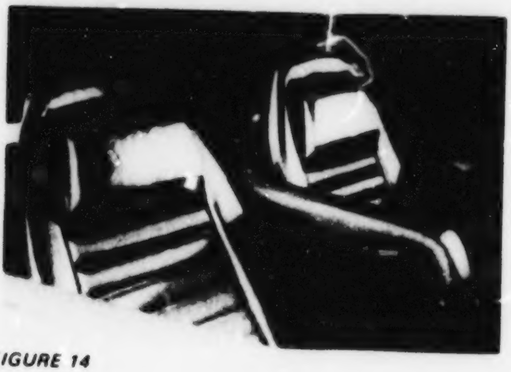


FIGURE 14

ENGINE/POWERTRAIN SYSTEM

The powertrain basically consists of current production units. The engine is 1.6L, 4 cylinder in line, and 102 hp at 6,000 rpm. Emission control devices are designed to meet 1973 Federal Standard.

Three-speed torque converter type automatic transmission is used. For easy operation and occupant safety in the case of secondary collision, the conventional control lever projecting into the cabin is removed, and instead of that, the position select is performed by the switch lever mounted on the steering column, which is actuated by an electric remote control system. A conventional 2-joint drive shaft and a rear axle housing for the independent suspension are also used.

BODY STRUCTURE

The most difficult problem we have faced in the development of this ESV is how to manage the body structure to meet the crashworthiness and occupant restraint requirements.

Front Body Structure

After conducting experiments by mofidied production models, and considering the reduction of aggressiveness and the occupant restraint system, we designed the layout of the front structure intending to hold the peak g within 40 and to make the average g to be 28. In this case, the crash travel is estimated to be 900 mm.

On the other hand, we conducted tests and analyses of the elements which absorb the energy by plastic deformation of the structural members. Figure 15 shows a static test of the energy absorbing S-type member.

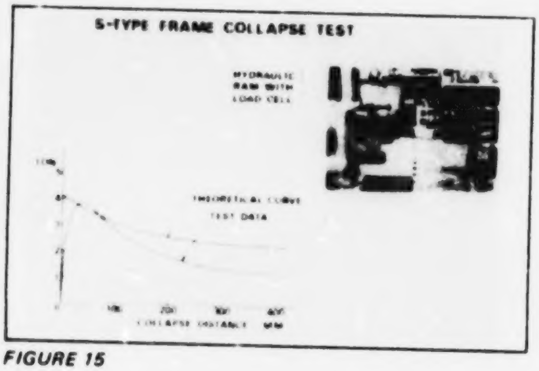


FIGURE 15

Figure 16 shows the modified car type 1. It has two energy absorbing S-type members in the lower portion and additional two members in the upper portion of the front body. They manage the impact energy and also they control the vehicle attitude during the crash period. Furthermore we composed a slide ramp between the fire wall and engine rear end, by which we can separate the engine downward in case of the crash in order to minimize the engine intrusion into the compartment. The crash travel in this case is estimated to be 1,300 mm. Figure 17 shows the results of fixed barrier and pole collision tests at impact speed of 80 km/h.

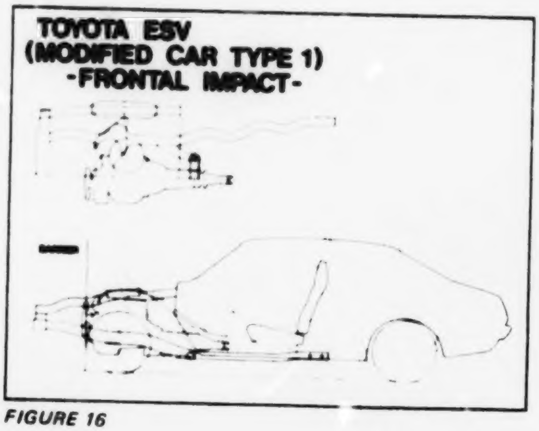


FIGURE 16

The result data showed obvious hardnose and the mode of energy management was not satisfactory.

But, on the other hand, the compartment intrusion was almost zero in the case of barrier impact.

Figure 18 shows the modified car type 2. The front body structure is similar to the one of previous type 1, but in this case we permitted the engine intrusion into the compartment about 100 mm and intended to absorb the collision energy by the members in front of the fire wall. The crash travel in this case is estimated to be 900 mm.

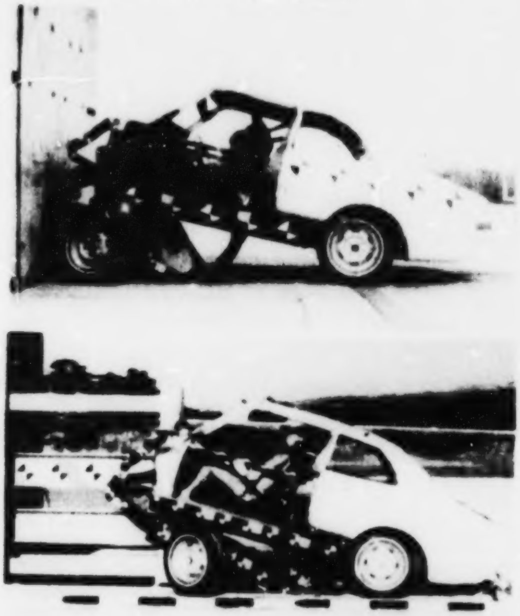


FIGURE 17

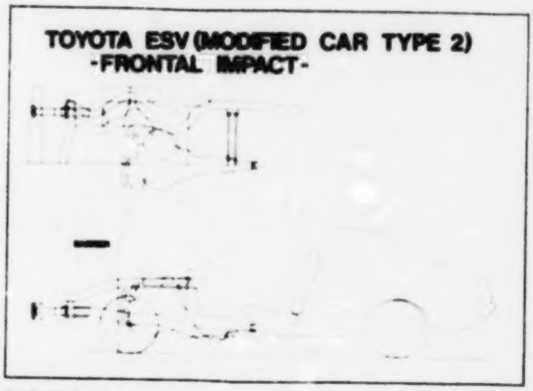


FIGURE 18

Figures 19 and 20 show the results of fixed barrier and pole collision at the impact speed of 80 km/h. The impact energy was managed within the front body deformation and no pitching action was observed.

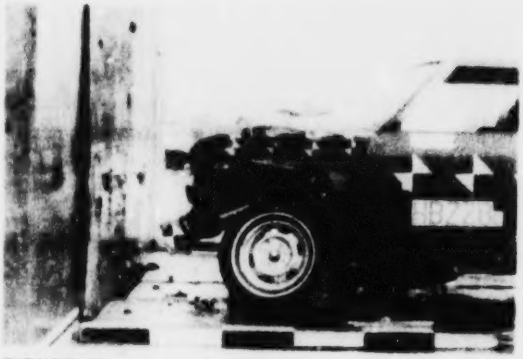


FIGURE 19

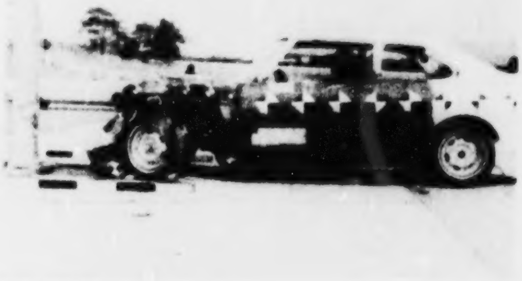


FIGURE 20

Figure 21 shows the g-time curve of these tests, and indicates the peak of 70 g in the case of barrier impact and 45 g in the case of pole impact. The compartment intrusion was measured at 150 mm in the case of barrier impact and 100 mm in the case of pole impact. Considering the results of these tests, we decided to design the first prototype by improving the body structure of type 2.

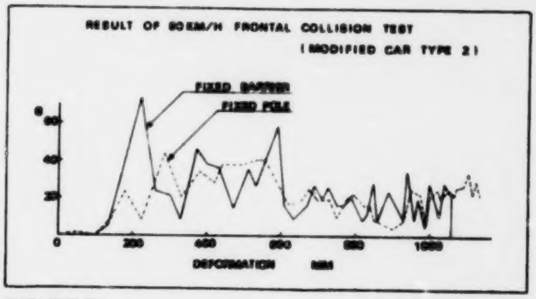


FIGURE 21

Rear Body Structure

Figure 22 shows the rear body structure. Underneath the luggage compartment floor, we have two energy absorbing members and installed the spare wheel flatly between these members. The actual crash travel, in the case of a 4,000 pound moving barrier impact at speed of 80 km/h, estimated to be 600 mm.

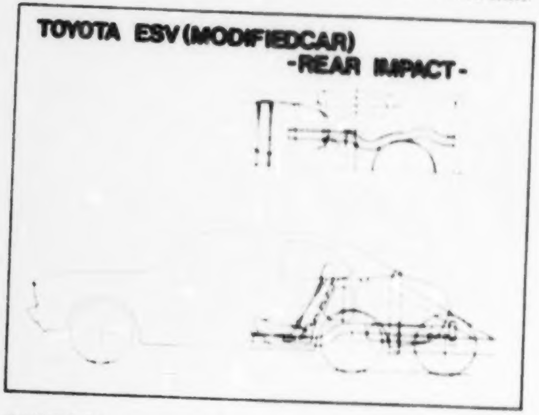

TOYOTA ESV(MODIFIEDCAR)
-REAR IMPACT-

FIGURE 22

Figure 23 shows the results of the rear end collision test of the perpendicular and the 15° angular moving barrier. We had the crash travel of 655 mm in the perpendicular position impact and 760 mm in the 15° angular position impact, and the compartment intrusion of 37 mm and 18 mm respectively. Also, there was no fuel spillage in either case. Figure 24 shows the g-time curve of these tests.

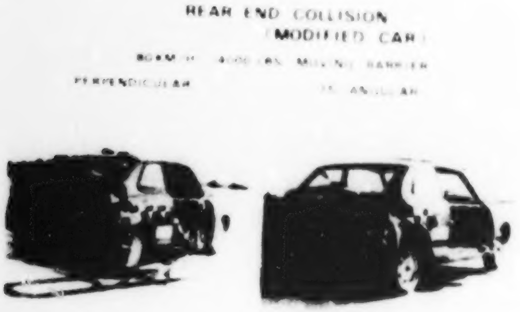

REAR END COLLISION
(MODIFIED CAR)
80KM/H 4000 LBS MOVING BARRIER
PERPENDICULAR
15° ANGULAR

FIGURE 23

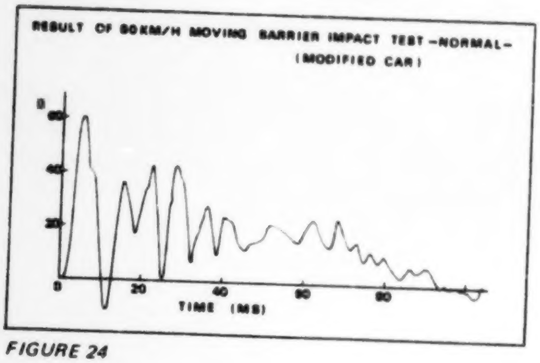


FIGURE 24

Side Body Structure

We have also side collision requirements of 50 km/h car-to-car and 25 km/h fixed pole. We intend to make the vehicle which can meet both car-to-car and pole collision requirements.

Figure 25 shows the results of the survey test of the production model. The compartment instusion was measured about 400 mm in both cases. Also we observed mutual impact of both heads, and significant g level was recorded. After study and analysis of these tests, we made a few modified cars as shown in figure 26. These modified cars had added door beams, side sill reinforcement and pillar reinforcement. Also, we expected the energy absorption by bumper shock isolator of the striking car. We designed energy absorbing door trims with 80 mm crush travel for the secondary impact of the occupant. In addition, we installed energy absorbing separator in between two seats to protect mutual head impact.

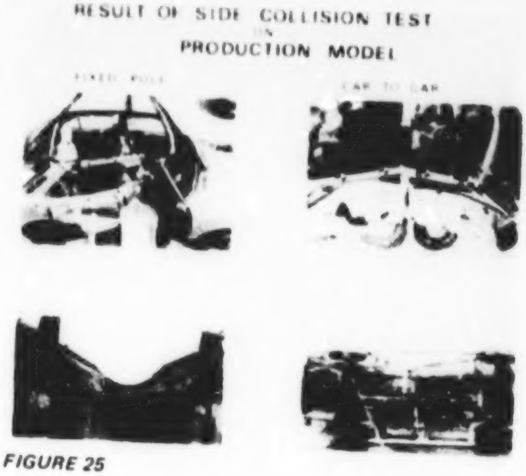

RESULT OF SIDE COLLISION TEST
ON
PRODUCTION MODEL
FIXED POLE
CAR TO CAR

FIGURE 25

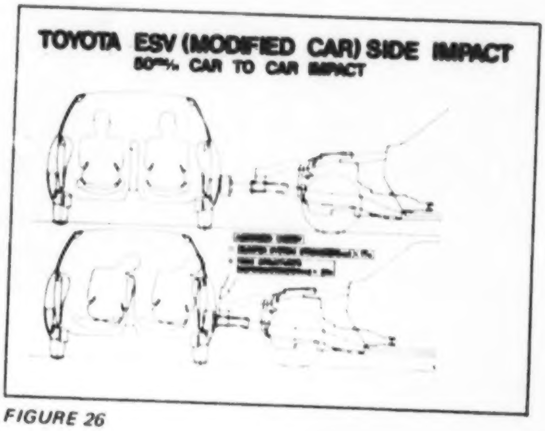

TOYOTA ESV (MODIFIED CAR) SIDE IMPACT
50km/h CAR TO CAR IMPACT

FIGURE 26

Figure 27 shows the car-to-car and the pole impact tests of the modified cars. The compartment intrusion did not exceed over 100 mm in both cases.

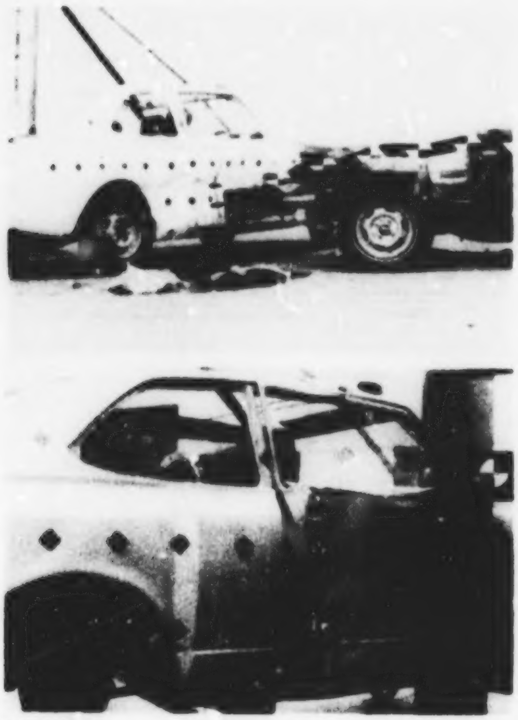


FIGURE 27

Figure 28 shows the bahavior of the dummy and dummy's g-time curve of the same test. The maximum deceleration g of the chest in the secondary collision was 40, and we did not observe mutual impact of both heads. But the head of the impacted side dummy moved out so much that it broke out the door glass, especially in the case of fixed pole impact. It hit the pole and fatal g level was recorded. We are now studying how to control the dummy's head.

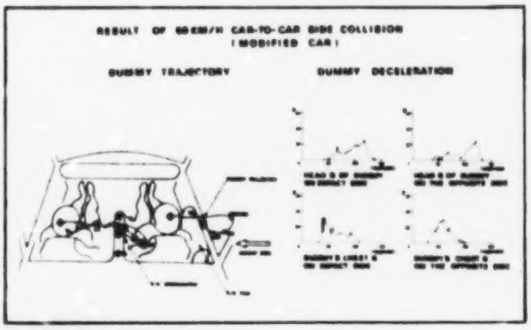

RESULT OF [illegible] CAR-TO-CAR SIDE COLLISION
(MODIFIED CAR)
DUMMY TRAJECTORY
DUMMY DECELERATION

FIGURE 28

Roof Structure

We are conducting a series of survey tests using production models and modified cars in accordance with the ESV specification.

Figure 29 shows the results of a 2-foot drop test of production model and modified car. The modified car had about 40 kg of added reinforcement.

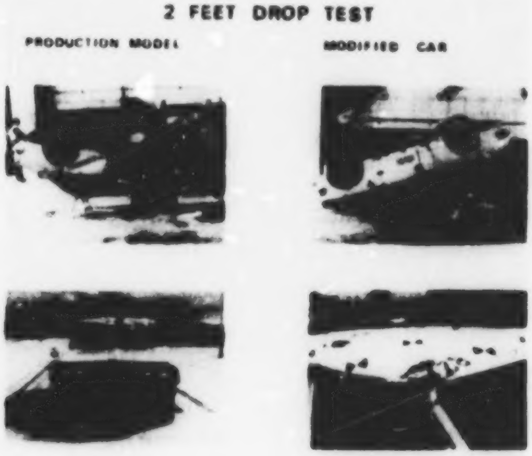

2 FEET DROP TEST
PRODUCTION MODEL
MODIFIED CAR

FIGURE 29

Figure 30 shows the rollover test by inclined dolly. The final speed of the dolly was 50 km/h and the test car rolled over twice. In this test, the compartment intrusion at the A-pillar was significant.

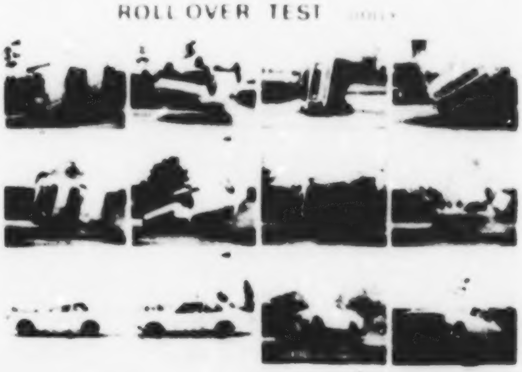

ROLL OVER TEST

FIGURE 30

On the other hand, we have conducted actual rollover tests under the SAE recommendation, but we think it questionable because of poor repeatability. In the first prototype, we are intending to improve compartment integrity and we think we can meet the specification.

BUMPER SUBSYSTEM

Figure 31 shows the bumper subsystem. This system is composed of a strong bumper bar and two velocity sensitive isolators. The design concept of this system is to meet the specification of low speed collision, to abosrb energy effectively at high speed collision and to reduce the aggressiveness to struck car.

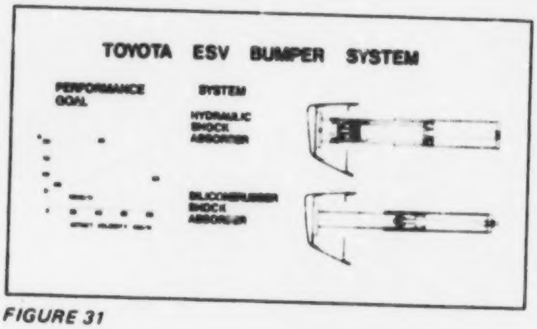


FIGURE 31

We designed the deceleration characteristics of the isolator to be 6 g at 15 km/h, and 20 g at 80 km/h. The bumper effective travel is designed to be 200 mm in the front and 130 mm in the rear.

We are testing two kinds of isolators; one, the hydraulic type, and the other the silicon rubber type.

Figure 32 shows a test of the bumper shock isolator unit at impact speed of 80 km/h.

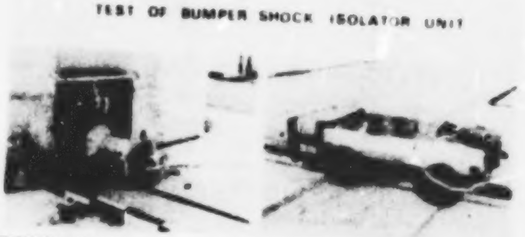


FIGURE 32

Figure 33 shows the test results of bumper shock isolator at the impact speed of 80 km/h and 15 km/h.

Figure 34 shows a test of bumper subsystem. As for the bumper bar strength, a lot of tests were conducted, and we decided tentatively the strength of the bumper bar to stand for 22 g in case of the pole impact at 80 km/h.

Figure 35 shows a test scene of the bumper subsystem in case of fixed pole impact at speed of 80 km/h. This shows that the primary energy management depends greatly on the bending of the bumper bar and the effective travel of the bumper shock isolators.

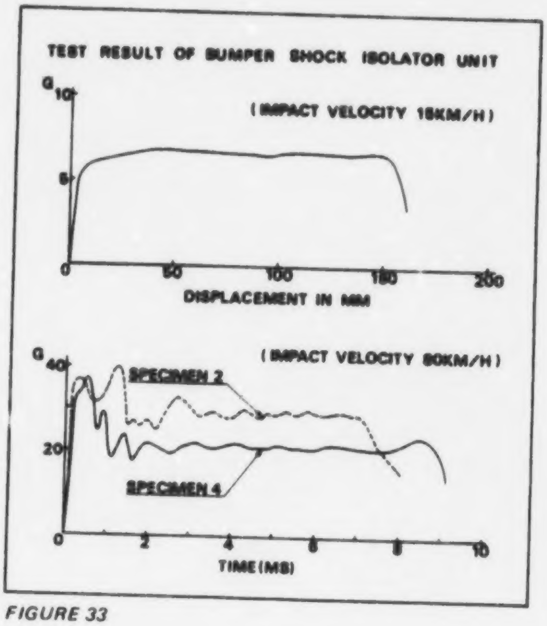


FIGURE 33

This bumper subsystem looks satisfactory experimentally, but practically we have problems. If the bumper system is designed with conventional materials, a front subsystem weighs over 60 kg and that does not mean the practical way.

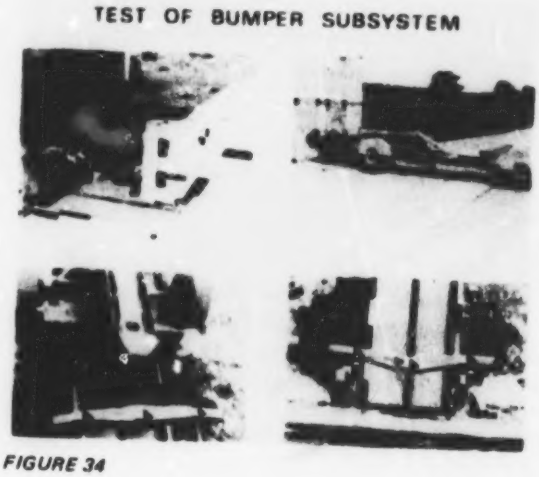


FIGURE 34

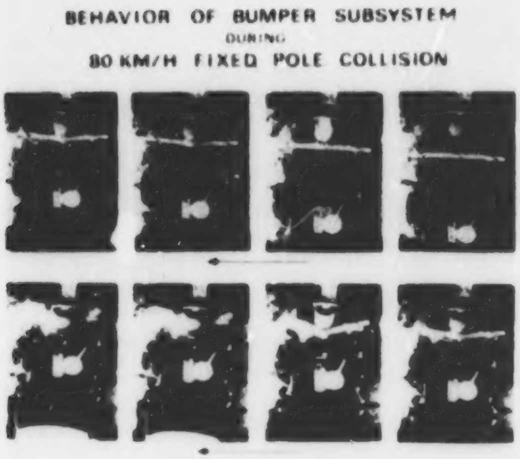


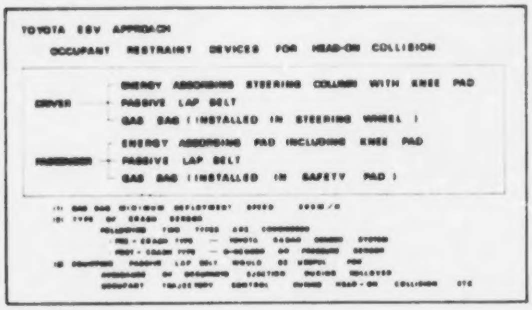
FIGURE 35

OCCUPANT RESTRAINT SYSTEM

The occupant restraint system is one of the main targets of this project, and we are concentrating our efforts to getting the best arrangement as a total system.

By observation of our basic test results, we have tentatively decided the design concepts of our first prototype as follows.

Figure 36 shows the concept. For driver seat we have an energy absorbing steering column, a passive lap belt and a gas bag which is installed in the steering wheel.



TOYOTA ESV APPROACH

OCCUPANT RESTRAINT DEVICES FOR HEAD-ON COLLISION

DRIVER
- ENERGY ABSORBING STEERING COLUMN WITH KNEE PAD
- PASSIVE LAP BELT
- GAS BAG (INSTALLED IN STEERING WHEEL)

PASSENGER
- ENERGY ABSORBING PAD INCLUDING KNEE PAD
- PASSIVE LAP BELT
- GAS BAG (INSTALLED IN SAFETY PAD)

(1) GAS BAG MINIMUM DEPLOYMENT SPEED 30KM/H
(2) TYPE OF CRASH SENSOR
FOLLOWING TWO TYPES ARE CONSIDERED
PRE-CRASH TYPE — TOYOTA RADAR [illegible] SYSTEM
POST-CRASH TYPE — G-SENSOR OR PRESSURE SENSOR
(3) [illegible] PASSIVE LAP BELT WOULD BE USEFUL FOR
PREVENTION OF OCCUPANTS EJECTION DURING ROLLOVER
OCCUPANT TRAJECTORY CONTROL DURING HEAD-ON COLLISION ETC

FIGURE 36

For passenger seat, we have an energy absorbing pad, a passive lap belt and a gas bag which is installed in the safety pad.

The designed minimum collision speed of gas bag deployment is 30 km/h.

As for the type of crash sensor, we are studying both ways, pre crash type and post crash type.

Also we are conducting sled tests for simulating the high speed collision with gas bag. Figure 37 shows the test.

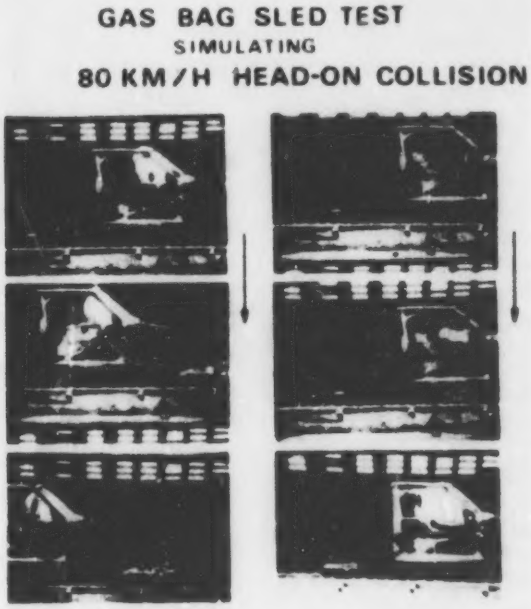


FIGURE 37

Figure 38 shows the results of high speed simulating sled tests and corresponding modified car's head on barrier collision test at impact speed of 80 km/h.

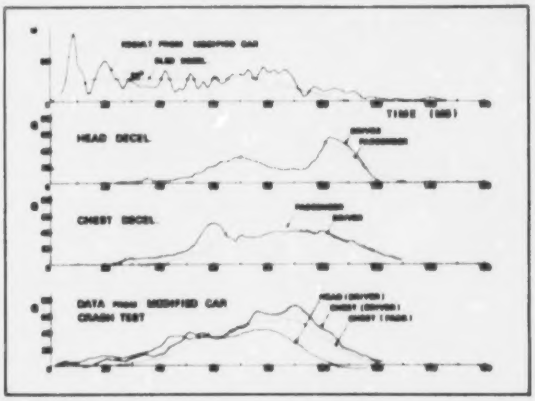


FIGURE 38

CONCLUSION

As I explained previously, Toyota has made some progress in the ESV development.

In the accident avoidance area, I think we have a possibility of accomplishing the same safety performance as in the full sized car.

And in the crashworthiness area I think there still remain difficult problems. We have severe limits of weight and space in a small sized car, but I expect we can satisfy the requirements of 80 km/h fixed barrier and pole impact which is considered the most difficult target in this project. In this case, I have to mention the following — the car which could meet the requirement is not the marketable one because of the economic and productive situations. Also the test results by which we could meet the requirements are only the result from unreliable test dummies.

I think to meet the specification for a dummy is one thing and to save human lives is another.

In view of the current mixed traffic environment the small sized cars face a difficult problem in the crashworthiness area against large sized cars.

Figure 39 shows a head on car-to-car collision test between our 2,000 pound class modified car and a full sized production model of 4,000 pound class at relative impact speed of 120 km/h. As I mentioned before our prototype is designed to have 900 mm of effective crush travel with average g of 28. In this car-to-car head on collision this small sized car spends all effective energy which could be absorbed, then the 4,000 pound large sized car has to absorb the rest of the total impact energy. We also can say the same thing in the case of car-to-car side collision, too.

I think by studying further these problems, the coexistence of both sized cars in the mixed traffic environment can be done safely in the future. I also think that the front body structure of the full sized car has to have some more improvements to reduce the aggressiveness against the small sized car.

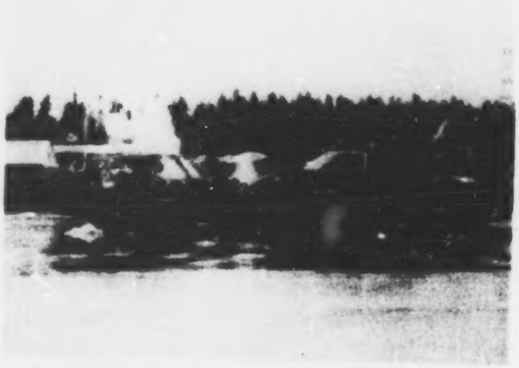


FIGURE 39

The curb weight of our first prototype is estimated to be about 1,150 kg as I mentioned before. We will continue the effort of weight reduction but it seems very difficult to make it within the specified 900 kg. Besides, it is questionable to us whether the requirement for a low speed collision at 15 km/h is worthwhile or not. For a small sized car in particular, the percentage of added weight to meet this requirement is rather great and it becomes unfavorable for a small sized car.

Now I would like to show you the movie films of our tests which we have conducted in these several months.

OCCUPANT PROTECTION OF 1,500 POUND ESV

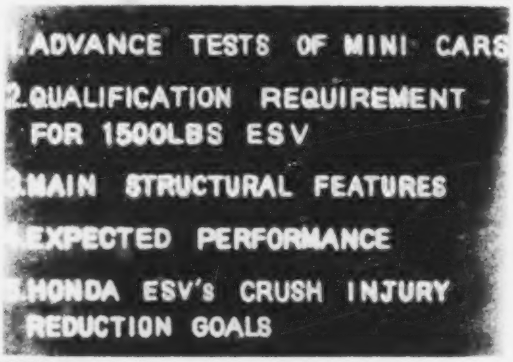
HIDEO SUGIURA, *Director*

Honda R&D Company, Ltd.

APPROACH TO
ESV

FIGURE 1

Our preliminary study on the Honda ESV has been carried out since September 1971. It is now at the stage of finalizing the basic concept on key items. At this time we would like to report on our progress made in occupant protection. Since the 1500 pound class ESV which Honda is challenging has some technical difficulties because of its small size, the biggest problem is to determine to what extent the small ESV can satisfy the various requirements of the ESV specifications. In considering this and other technical difficulties, our present goal may have to be readjusted to meet existing technology. While explaining the advance testing carried our during this period, we wish to explain the results of our preliminary evaluation of the 1500 pound class ESV.



1. ADVANCE TESTS OF MINI CARS
2. QUALIFICATION REQUIREMENT FOR 1500LBS ESV
3. MAIN STRUCTURAL FEATURES
4. EXPECTED PERFORMANCE
5. HONDA ESV's CRUSH INJURY REDUCTION GOALS

FIGURE 2

ADVANCE TEST OF SMALL SEDAN

In order to clearly define problems peculiar to small cars, a series of collision tests was conducted on our smallest production model.

Head-On Barrier Collision Test

Normal at 30 mph

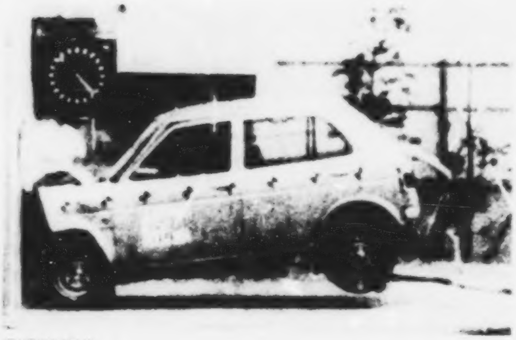


FIGURE 3

Normal at 40 mph

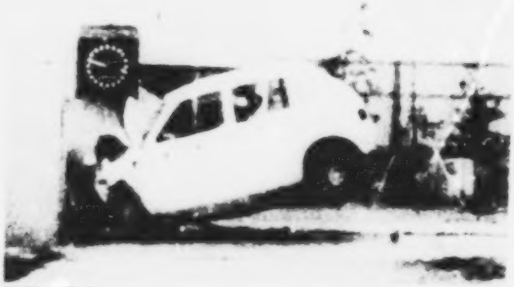


FIGURE 4

Normal at 50 mph

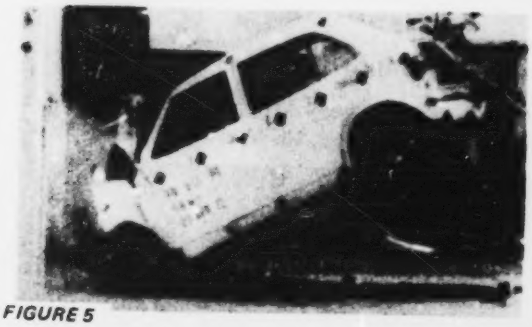


FIGURE 5

45° at 30 mph

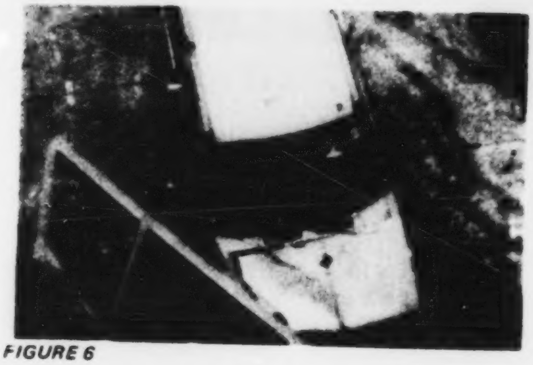


FIGURE 6

Head-On Pole Collision Test at 50 mph

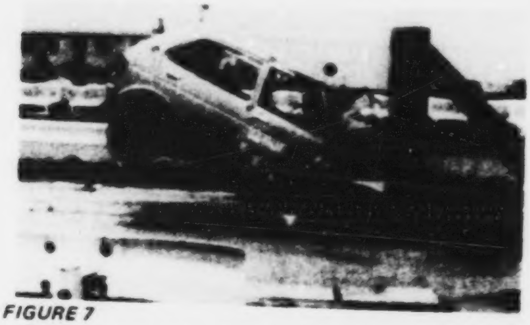


FIGURE 7

Rear-End Collision by Moving Barrier at 30 mph

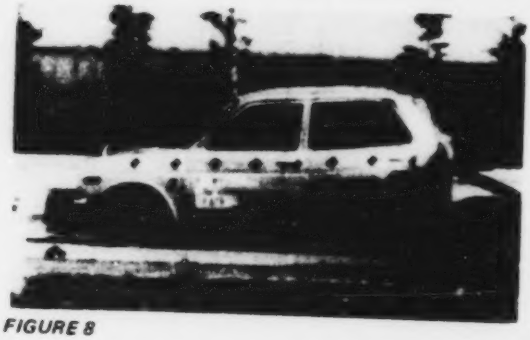


FIGURE 8

The results indicated that with the present production small car, a 30 mph impact which is far from meeting the impact speed requirement goal established in the ESV specifications, produces a deceleration of 90 g at the head area and 50 g on the floor.

FIGURE 9

Naturally safety devices such as seatbelt systems, airbags, etc. that are decisive factors for occupant protection are currently under development to improve their effectiveness as individual subsystems. By incorporating such improvements, the maximum impact velocity at which occupants can be protected within the size of a small car (overall length 3,000 mm and overall width 1,300 mm) can be expected to increase somewhat. In order to improve crash performance the most reasonable solution would be the extension of frontal body length.

However, since the design of the Honda ESV has been initiated with a concept of a light weight of 1500 pounds, compactness and overall utility, there is a limit beyond which the body length of the Honda ESV cannot be extended. Honda's effort in realizing its ESV is being made within these limits.

QUALIFICATION REQUIREMENTS FOR THE 1500 POUND ESV

The value of small vehicles in a world-wide view is as stated in our previous report and this also is supported by the demand for such vehicles. We intend that our 1500 pound ESV will occupy a position among these small popular cars.

Vehcile Shall Be Based On Small Car Concept

As a means of personal transportation, such small popular cars having easier maneuverability and handling in congested city traffic and less gasoline consumption thereby conserving fuel resources are being given another look and their advantages are being widely recognized. Therefore since the dimensions and weight are limited, it is necessary to seek the optimum safety within these restrictions. The specific body specifications of such a small ESV estimated on the current small popular cars would be a total projected area of 5.5 to 5.8 m², overall length of approximately 3.5 to 3.8 m, overall width of 1.4 to 1.5 m, and curb weight of approximately 750 kg. The Fiat 127 and 850 and Renault 5 among European cars, and the Toyota Publica and Nissan Cherry among cars in Japan may be cited as representative of such vehicles.

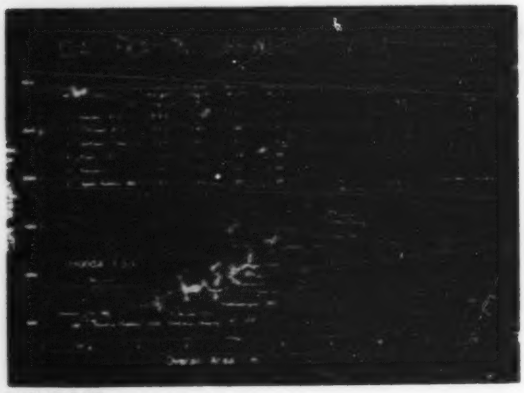


FIGURE 10

Cost-Benefit Balance

Although there are a number of safety related matters, the order of their importance must be clearly established. The most important are naturally accident avoidance and assurance of occupant survivability. Less important are repair cost reduction and crash performance at low velocity. Every effort must be made to attain the most reasonable weight, cost and benefit balance. Moreover, the materials to be used should be based on materials generally available for production and the use of special materials should be avoided as much as possible.

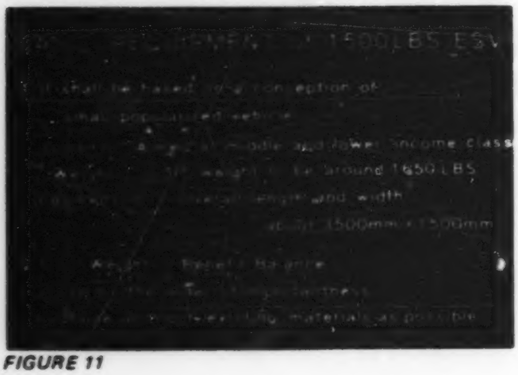
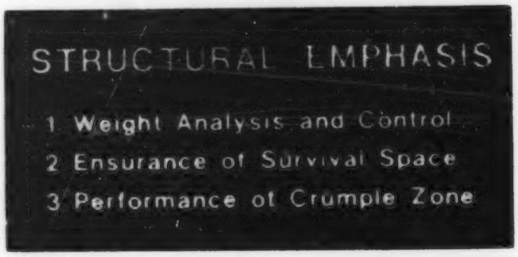


FIGURE 11

MAIN STRUCTURAL FEATURES

Main structural features of the projected Honda ESV can be described as follows.



STRUCTURAL EMPHASIS

1 Weight Analysis and Control

2 Ensurance of Survival Space

3 Performance of Crumple Zone

FIGURE 12

Weight Analysis

We have been considering the weight distribution appropriate for occupant safety within the allowable weight limit. This slide shows an outside view of the Honda ESV and the placement of each device and the distribution of its additional weight. From each end of the vehicle, a bumper, E.A. (energy abosrber) unit and compartment are assembled in this order, with the occupant protective device in the compartment. Increase in weight due to these devices amounts to approximately 132 kg (291 pounds).

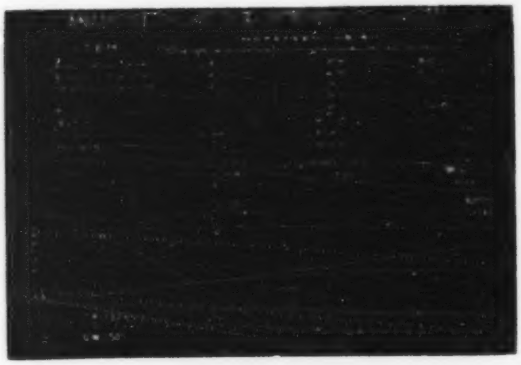


FIGURE 13

This figure is a result of calculation assuming that the lightest available materials are used on the basis of a small family sedan with a projected area of 5.3 m². If the required balance of cost, weight and production feasibility is taken into account as stated previously the weight increase is 208 (458 pounds) and the resultant curb weight would be 846 kg (1,865 pounds). This 846 kg is our target figure for weight control.

Ensuring Survival Space

If the required cross section of each member is established on this outside contour so as to withstand front and rear end collisions as well as rollover, with the interior occupant protective device installed, the inside space becomes extremely limited as seen in this slide. As a result, it can only ensure a minimum survival space for a 95th percentile adult male in the rear seat.

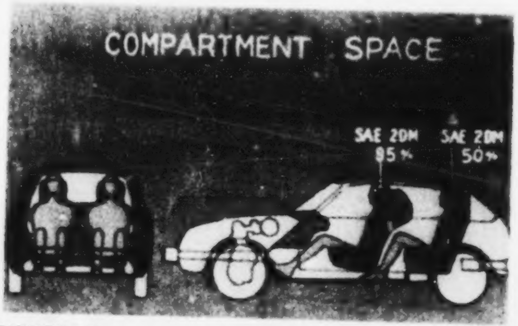

COMPARTMENT SPACE
SAE 20M 95%
SAE 20M 50%

FIGURE 14

Therefore, to lessen fatal injuries due to the impact intrusion, the survival space for occupants must be ensured by increasing the stiffness of the compartment against deformation as a result of collision. This necessity is far greater for smaller vehicles than larger vehicles. By studying efficient arrangement of members within the weight permitted, we have proceeded with a structural design which distributes the collision forces in a manner intended to minimize the overload on any one member.

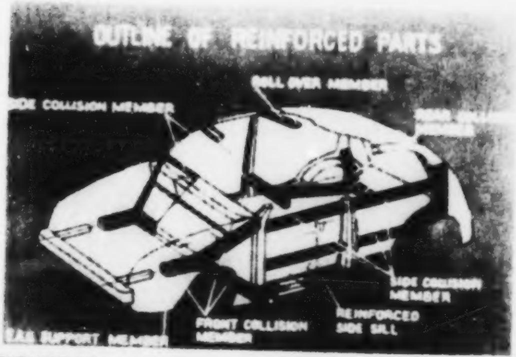

OUTLINE OF REINFORCED PARTS
ROLL OVER MEMBER
IDE COLLISION MEMBER
SIDE COLLISION MEMBER
REINFORCED SIDE SILL
FRONT COLLISION MEMBER
E.A.U SUPPORT MEMBER

FIGURE 15

This slide shows the members installed on the original car on priority basis. It is established to withstand 40 g against frontal impact, and it is of flat, four-phase construction consisting of dashboard, toeboard and cowlboard, with four members installed through its ridge to bring about a reinforcing effect of the panels and members. Rear impact is to be received by longitudinal members extended from the side sills. For side impact, the beams inside the doors, a lateral beam connecting RH and LH B-pillars and a roof arch are provided. The roof arch also serves to minimize deformation of the roof in the event of rollover.

Performance Of Crush Zone

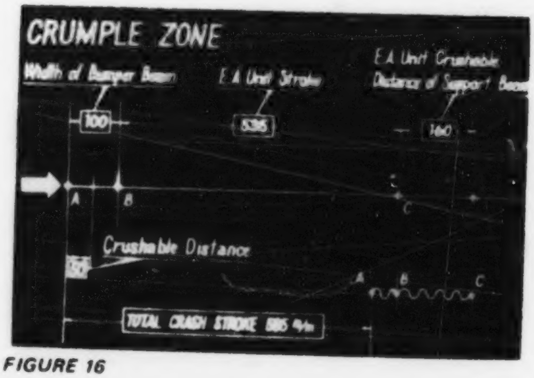

CRUMPLE ZONE
Width of Bumper Beam
E.A Unit Stroke
E.A Unit Crushable Distance of Support Beam
100
535
160
A
B
C
Crushable Distance
50
A
B
C
TOTAL CRASH STROKE 585 m/m

FIGURE 16

Since crush distance is particularly limited in small cars, effective utilization of the available space is required. In order to make the maximum use of crush distance, the Honda ESV is designed so that 50 mm (2 inches) of the bumper beam and 160 mm (6 inches) of the E.A. unit supporting beam at the end of the compartment collapse. Combined with the E.A. unit this provides a crush allowance of 585 mm (23 inches) in total. By reserving as much crush distance as possible for occupant protection, the performance of the bumper in low velocity crashes is limited to up to 8 k/h collisions.

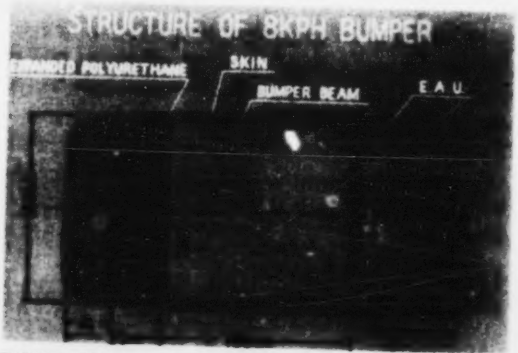

STRUCTURE OF 8KPH BUMPER
XPANDED POLYURETHANE
SKIN
BUMPER BEAM
E A U

FIGURE 17

CHARACTERISTICS OF 8KPH BUMPER

BUMPER WEIGHT	10kg
DECELERATION AT 8KPH	10 ~ 11G
MAX DEFORMATION	40 ~ 45mm
REBOUND VELOCITY / IMPACT VELOCITY	0.45 ~ 0.48
URETHANE FOAM DENSITY	0.11 ~ 0.12 g/cm³

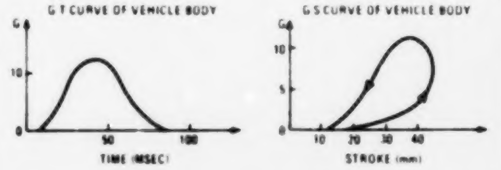


FIGURE 18

Shown here is an 8 k/h bumper and its characteristics are described.

LENGTH OF E.A.: 732

FIGURE 19

Next, the E.A. unit was designed to make use of the plastic deformation feature of the material and it has square wave energy absorption characteristics. The unit manufactured for experiments is of 80% energy absorption efficiency and has 70% effective stroke.

In an effort to provide optimum crash protection, we are currently studying, from various angles, the possibility of improving vehicle deceleration characteristics and the occupant protection system in addition to utilizing the distance of 585 mm obtainable with this construction. The specific predicted performance is described next.

EXPECTED PERFORMANCE

(Mathematical Analysis on Occupant Protection)

When a frontal barrier collision was conducted at 50 k/h on an unmodified current production vehicle to be used as a base for the Honda ESV, with a seated dummy equipped with a conventional three-point seat-belt system, the injury criteria was generally met. We decided to increase the occupant protection by providing the maximum possible crush distance within the limited size of vehicle and also to improve the performance of the seat belt system to the best of our ability. As a method to expedite the development process, we made a rough estimate of expected performance through calculation by a computer.

Some of the results are shown in the following films.

Occupant Protection By Mathematical Analysis (Head-On Barrier Collision)

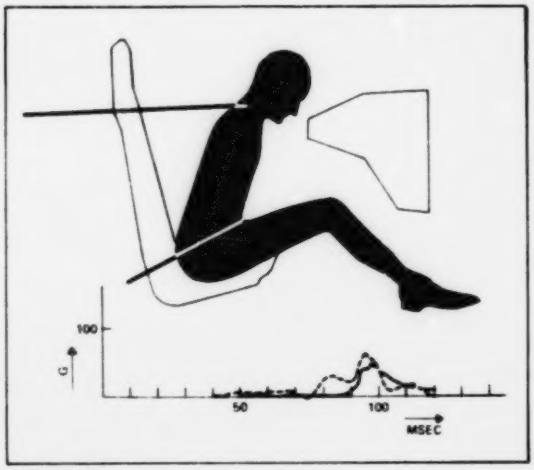


FIGURE 20

This is a computer simulation of a collision test conducted at 50 k/h on an unmodified current production vehicle. The results obtained by simulation are close to the injury criteria levels in the ESV specification. Very similar results have been obtained in actual crash testing. Therefore the computer simulation appears to be a reasonable approximation of actual vehicle crash testing.

ESV With Conventional Three-Point Seat Belts (50 mph)

We assumed a case where a vehicle having a crush distance of 585 mm, with a seated dummy equipped with a conventional three-point seat belt system, is subjected to a barrier collision test at 80 k/h with the E.A. unit working effectively to absorb energy at the most efficient waveform. As a result, the head deceleration of the dummy exceeds the allowable

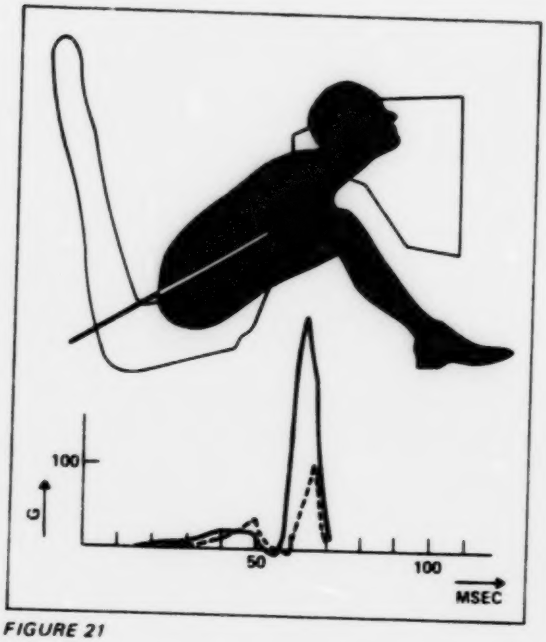


FIGURE 21

limit of 80 g by a great deal reaching as high as 150 g. The shoulder belt breaks off, with the head impacting the instrument panel.

ESV With Energy Absorbing Belts (50 mph)

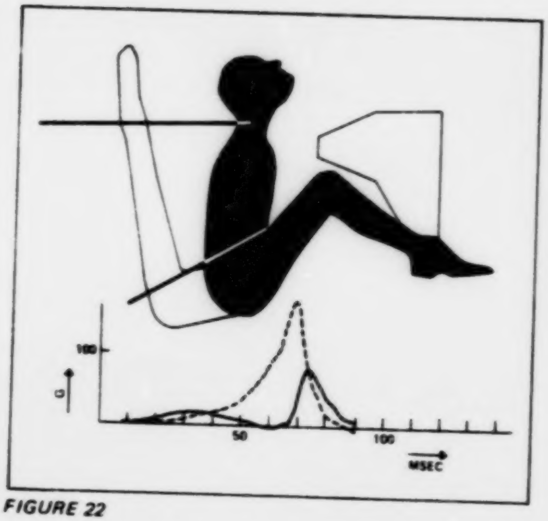


FIGURE 22

Next, supposing a dummy equipped with an energy absorbing belt (an improved seat belt system), the head deceleration decreases, but is not yet below 80 g.

ESV With Energy Absorbing Belts (45 mph)

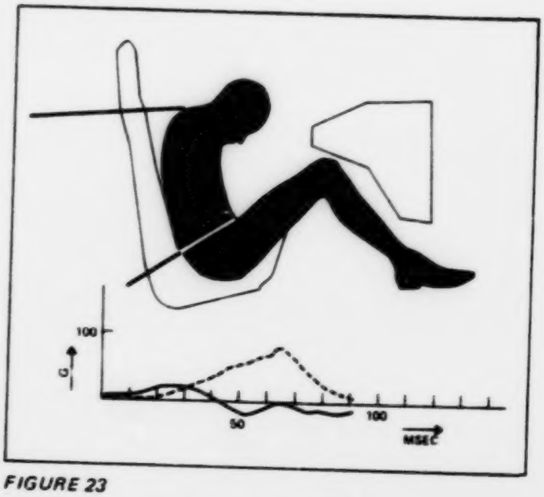
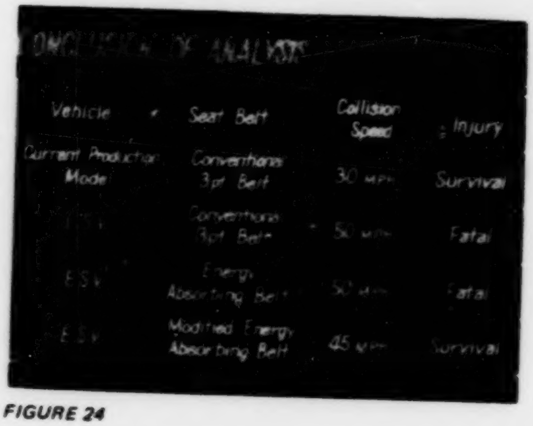


FIGURE 23

If the seat belt system is improved in energy absorption performance with a lap belt and shoulder belt combined to produce optimum characteristics and in addition the crash velocity is reduced from 80 k/h to 70 k/h, the head deceleration decreases to approximately 80 g.

From the results of calculations, we conclude as follows:



ONCLUSION OF ANALYSIS

Vehicle	Seat Belt	Collision Speed	Injury
Current Production Model	Conventional 3pt Belt	30 MPH	Survival
[illegible]	Conventional 3pt Belt	50 MPH	Fatal
ESV	Energy Absorbing Belt	50 MPH	Fatal
ESV	Modified Energy Absorbing Belt	45 MPH	Survival

FIGURE 24

1. Due to the restriction of the crush distance, it is difficult to provide efficient occupant protection in a barrier collision at 80 k/h.
2. With an improved seat belt system (energy absorption performance and an optimum combination of lap and shoulder belt), occupant protection performance will be improved significantly.
3. It is reasonable for a Honda 1500 pound class ESV to set the goal at 65 to 70 k/h.

HONDA ESV'S CRASH INJURY REDUCTION GOALS

On the basis of the foregoing, we propose a specification for Honda ESV crash injury reduction as follows:

Frontal Collision

1. Front bumper collision at 8 k/h.
2. Frontal barrier collision at 65 k/h.
3. 15° barrier collision at 65 k/h.
4. 45° barrier collision at 50 k/h.
5. Car-to-car frontal collision at a relative velocity of 95 k/h.
6. Head-on pole collision at 50 k/h.

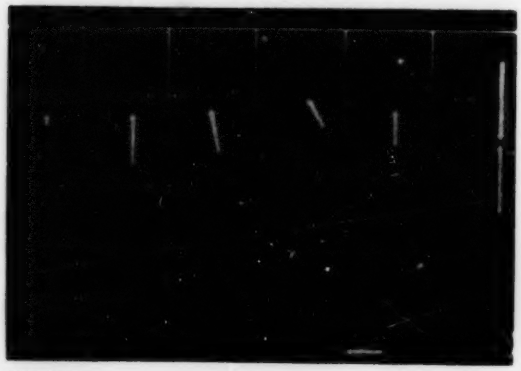


FIGURE 25

Rear-End Collision

1. Rear bumper collision at 8 k/h.
2. Rear-end moving barrier collision at 65 k/h.
3. 15° moving barrier collision at 65 k/h.
4. 45° moving barrier collision at 40 k/h.
5. Rear-end collision between equivalent weight vehicles at a relative velocity at 80 k/h.
6. Moving rear end pole collision at 15 k/h.

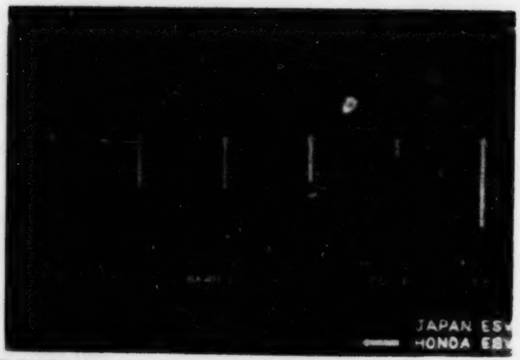


FIGURE 26

Side Collision and Rollover

1. Side collision between equivalent weight vehicles at 50 k/h.
2. Crash against a fixed pole at 25 k/h.
3. Rollover test comprising not less than two rollovers.

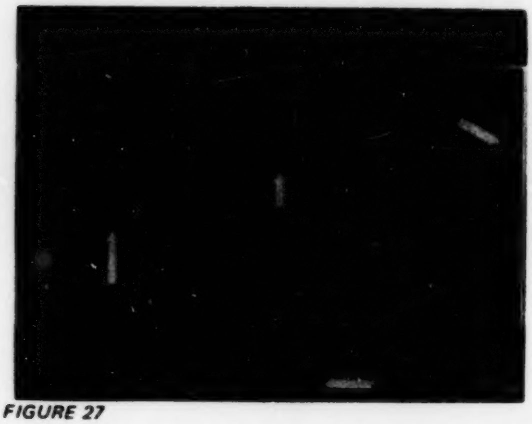


FIGURE 27

In accordance with the 15 conditions listed above, we set a goal of meeting the injury criteria and occupant survival space requirements of the Japan ESV specifications.

THE UNITED STATES TECHNICAL PRESENTATION

SECTION 2 PART 7

EXPERIMENTAL SAFETY VEHICLE – PHASE TWO – DESIGNED AND DEVELOPED BY GENERAL MOTORS

MR. J. W. ROSENKRANDS; *ESV Program Manager*

General Motors Environmental Activities Staff

INTRODUCTION

This report presents the last chapter in the story of the Experimental Safety Vehicle developed by General Motors under contract with the U.S. Government Department of Transportation. This undertaking began two years ago, as a part of Phase Two of the U.S. Government's ESV program.

Within the past 24 months, General Motors has developed two series of ESV prototypes. This work has been profitable in terms of knowledge gained. Our experimental safety research work in total system development, which has been going on for many years, will continue long after this contract ends.

At the Second International ESV Conference last October in Stuttgart, the General Motors first design was described in detail, and the results of testing that vehicle were reported. Since the significant revisions have been made, and a rather large test program completed. The General Motors design derived from these tests and revisions is presented here.

This discussion relates to the philosophy of our program, the overall results that have been achieved, and the significance of the work – what has been learned and also what some of the many remaining questions are. It contains information on vehicle mechanical development and interior development. It relates to the final report, which was submitted at the end of the contract on June 30, 1972.

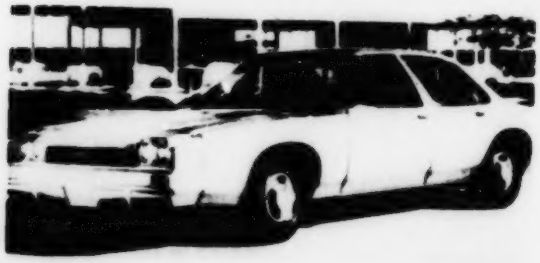
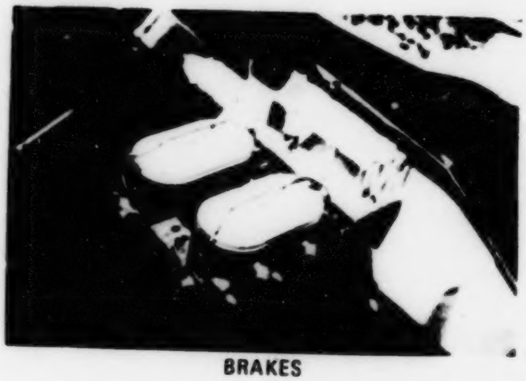


FIGURE 1

General Motors considers the ESV (Figure 1) to be an idea car, an opportunity for testing safety ideas – some new, and some old. The combining of these ideas into a new vehicle, to be fabricated on production-type tools, has been a significant assignment. Some of the highlights of the GM safety vehicle are:

FIGURE 2



BRAKES

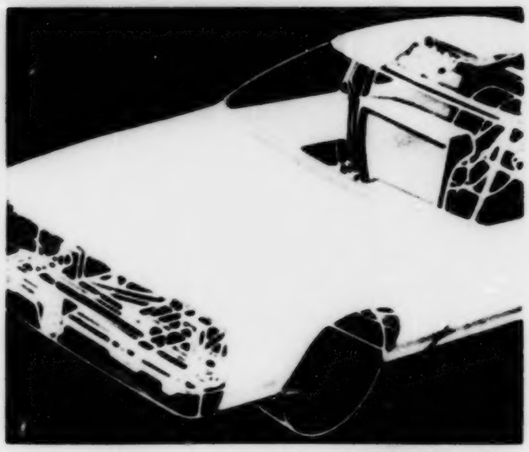
The braking system (Figure 2) features four-wheel disc brakes, with automatic wheel-lock controls throughout, and front-to-rear proportioning.

FIGURE 3

BRAKES WINDSHIELD PILLAR

- Elimination of the windshield pillar (Figure 3) has provided panoramic vision and a new approach to hardtop styling.

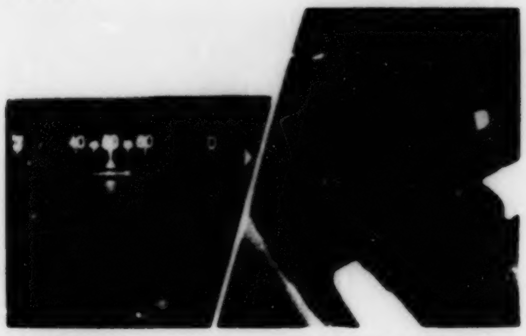
FIGURE 4



BRAKES ALUMINUM
WINDSHIELD PILLAR

- The aluminum body results in significant weight savings without loss of structural integrity (Figure 4). Without its use, the car would be prohibitively heavy.

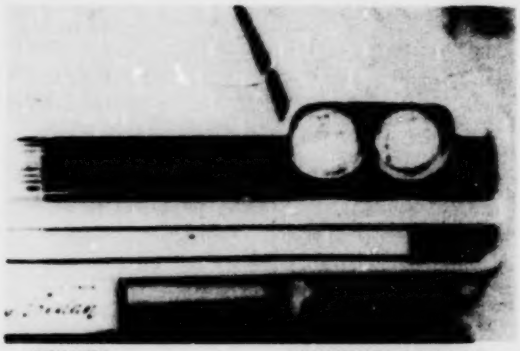
FIGURE 5



BRAKES WINDSHIELD PILLAR
ALUMINUM MESSAGE CENTER

- Primary and secondary message center instrumentation provides extra information to the driver. Figure 5 (right half) shows the secondary message center in a console between the two front seats, where its placement reduces driver distraction. He sees only vital information in the primary message center (Figure 5, left).
- Low-speed barrier impact bumper units (Figure 6), with large areas both front and rear, eliminate body damage in barrier crashes up to 5 mph.

FIGURE 6



BRAKES WINDSHIELD PILLAR
ALUMINUM MESSAGE CENTER
BUMPERS

FIGURE 7

BRAKES WINDSHIELD PILLAR
ALUMINUM MESSAGE CENTER
BUMPERS DECK LIDS

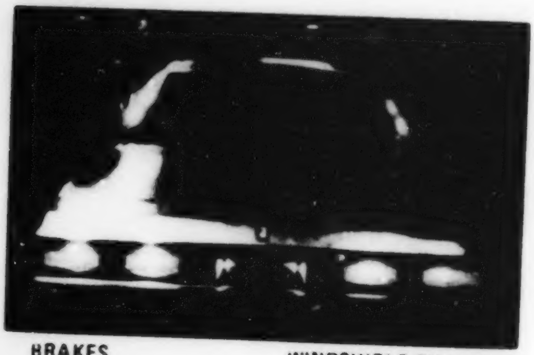
The side opening rear deck with 1/3 – 2/3 divisions affords a new concept in curb-side loading (Figure 7).

FIGURE 8

BRAKES WINDSHIELD PILLAR
ALUMINUM MESSAGE CENTER
BUMPERS FIXED GLASS
DECK LIDS

- Fixed side glass is intended to keep occupants within the safer confines of the passenger compartment in certain accident situations (Figure 8).

FIGURE 9


BRAKES
ALUMINUM
BUMPERS
FIXED GLASS
WINDSHIELD PILLAR
MESSAGE CENTER
DECK LIDS
HIGH LEVEL SIGNALS

- High level rear signals with dual levels of brightness (Figure 9). This means improved visibility of stop and turn signals, both day and night.

FIGURE 10

BRAKES
ALUMINUM
BUMPERS
FIXED GLASS
INTERIOR
WINDSHIELD PILLAR
MESSAGE CENTER
DECK LIDS
HIGH LEVEL SIGNALS

- And last, an all-enveloping interior and occupant protection system (Figure 10). The design of this occupant protection system is considered to be the most important and challenging portion of this assignment.

As the various ESV contractors finish their prototypes, design similarities and differences between them are of interest. One fundamental difference is the way in which the kinetic energy is dissipated during a high-speed barrier crash. The GM philosophy is that, for system efficiency and weight control, no part of the structure – inside or outside – ought to be any stronger than necessary to do its job of keeping forces on the dummies within the specified limits (Figure 11).

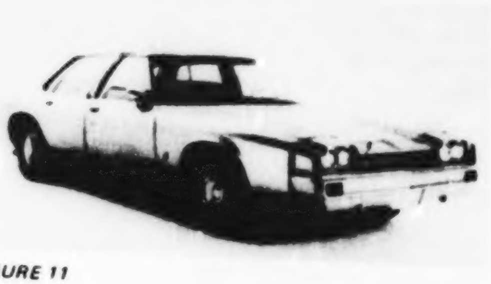


FIGURE 11

Although the contract only specifies impact testing against barriers, poles and other ESV's, consideration must be given to cases where the bumper overlap might be insufficient to insure that the crash forces would follow the prescribed path.

Use of plastic deformation of structural metal was chosen as the method to absorb the energy (Figure 12), based first on the requirement to keep weight as low as possible; and second, on the versatility that could be achieved with respect to impact direction.

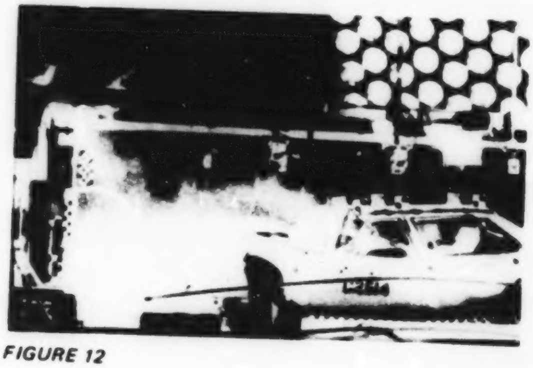


FIGURE 12

In our first design, which was shown in Stuttgart, a bumper system with 9-inch stroke and the specified 10 mph no-damage capability was superimposed and calculated into the energy management system both in the front and in the rear. While this was a reasonable arrangement, it was found that peak decelerations on the vehicle could be reduced by making better use of the precious 9 inches of bumper stroke.

For the final design, a 5 mph no-damage bumper concept with a stroke of 2.5 inches was chosen. This made it possible to weaken the frame selectively. To take advantage of the space available for new structure, load carrying aluminum members (Figure 13) were extended forward of the radiator. At the same time, reinforced tie-ins between the door hinges and lock pillars were developed. Because new parts were necessary to obtain the new structure, weight optimization was possible in many areas. The doors, for example, weighed 30 pounds less than in the first design.

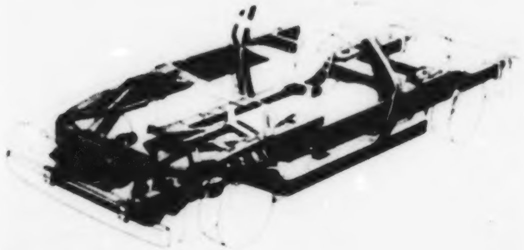


FIGURE 13

The occupant protection system (Figure 14) was tailored to simplify the problem. The most basic change was lowering the car speed at which the air cushions were deployed from 30 mph to the contract speed of 20 mph. The beam in front of the rear occupants was rigidly attached to the center pillars. Knee panels with honeycomb-type energy absorbing material replaced the front occupants' knee cushions and movable knee panels, and the remaining air cushions were further tailored.

Accepting the decision to have our ESV deform in a crash, a review of rationales for the selection of crash tests to validate the design is appropriate. Working with 56 pages of contract and only 11 cars, some choices were necessary and justified.

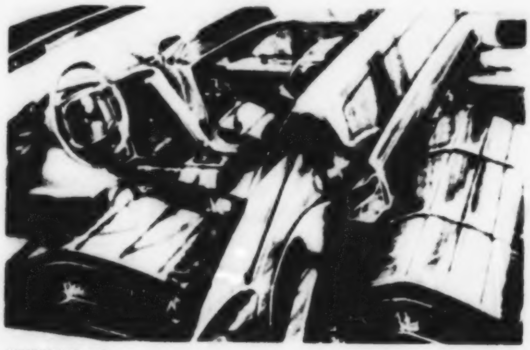


FIGURE 14

The technique involved analytically selecting the toughest tests in each of the various categories of crashes (Figure 15). Choices were made on the basis of structural severity and occupant severity, as these are by no means always the same.

ESV CONTRACT IMPACT CONDITIONS

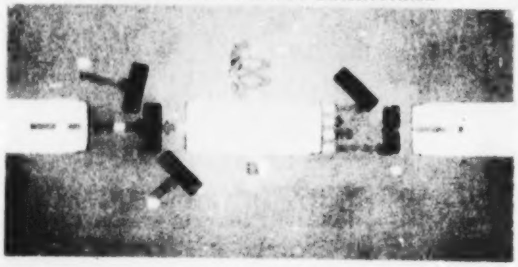


FIGURE 15

The 50 mph front barrier test (Figure 16) was considered one of the most severe for the structure, because the highest level of deceleration is experienced in this test, and it is *the* test for the cushion system.

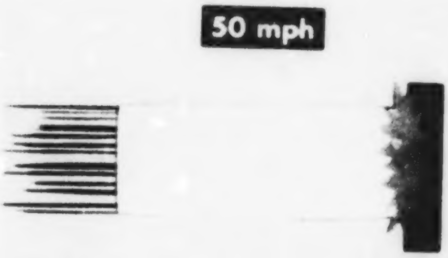


FIGURE 16

The 50 mph front pole impact (Figure 17) was selected as probably the most severe for the structure. If these two tests could be passed, then other similar tests, such as 15° angles to poles and barriers and 75 mph car-to-car closures, would also be covered. This reasoning is valid with our design where the structural behavior is not highly sensitive to direction.

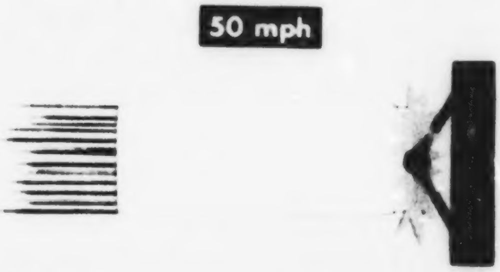


FIGURE 17

At the rear, the 50 mph flat moving barrier was considered the most severe rear structural test. This covered also the small angle test at the same speed specified in the contract.

The dolly rollover (Figure 18) and the roof drop tests were run, while the 60 mph rollover was not. Repeatability was a foreseen problem with this test and it did not appear to represent a more serious test of the interior than the dolly rollover. The lower speed corner and side impacts were also conducted to evaluate the passive interior.

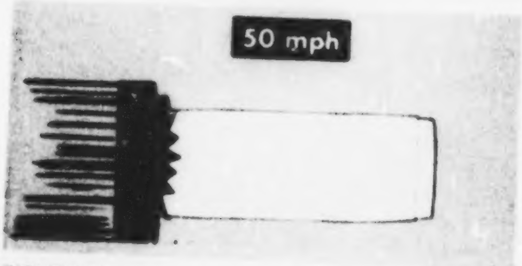


FIGURE 18

The 50 mph flat barrier test (Figure 19) took place in February. The change to a 5 mph bumper system proved worthwhile in controlling undesired vehicle motion. A view through the windshield (Figure 20) showed the proper air cushion timing, but the driver cushion proved to be too soft. The trajectories of the dummies provided no surprise; all occupants came much closer to contract survival than in earlier tests. The underbody deformation showed the effect of selective weakening of the frame, and the system performed as designed.

In the next test, hitting the pole at 50 mph resulted in 52 inches of dynamic deformation. Again, the body attitude is well controlled throughout the crash. The deformation is most graphically portrayed in this overhead camera view (Figure 21). Intrusion into the passenger compartment is minimal. Again, the driver cushion did not develop enough pressure. However, measured accelerations on all four passengers were within specifications, and the doors could easily be opened after the crash.

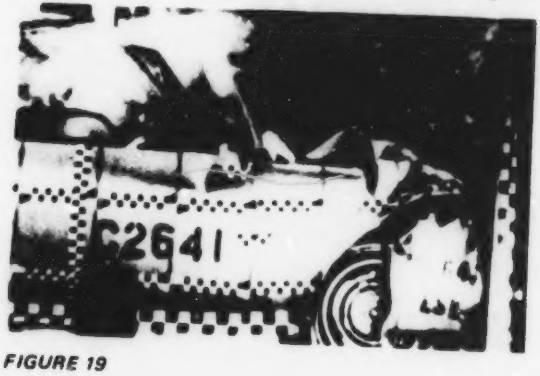


FIGURE 19

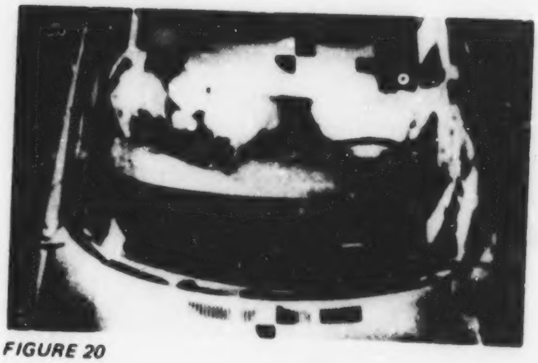


FIGURE 20

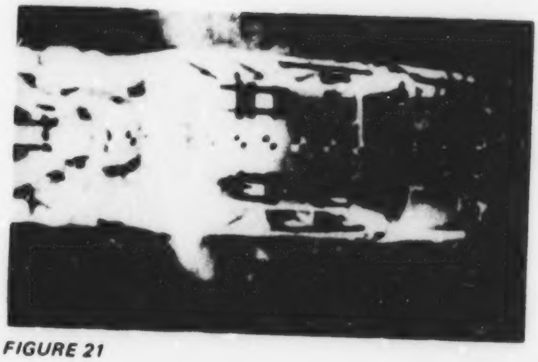


FIGURE 21

The 30 mph impact into the 45° barrier proved to be a very easy test to pass. A similar conclusion was reached for the rear quarter impact. G loading on the corner was not sufficient to trigger the air cushions, but the padded interior functioned properly and the occupants stayed apart, even in rebound. In a passive interior with extensive padding, the hardest object to be encountered in a crash of this type is the head of another dummy. The initial dummy motion comes from the front corner impact, but the final gyrations are caused by the second impact when the rear quarter of the yawing vehicle hits the barrier.

The front diagonal bracing of the frame buckled properly under 45° loading and deformation proved to be almost identical to the computer's advance prediction.

Figure 22 shows the 50 mph rear moving barrier impact. Deformation was successfully limited to a dynamic 32 inches. The cloud rising from the impact area is from the discharge of the energy absorbing bumper cylinders. No gas was spilled. The occupants stayed in their seats very nicely throughout the test.

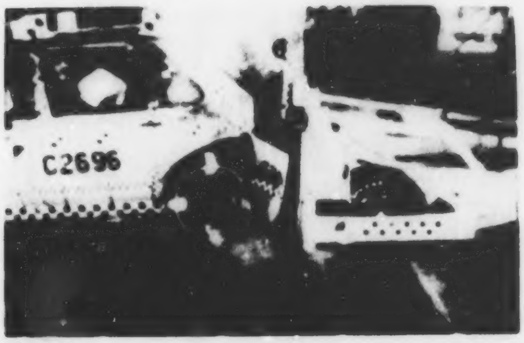


FIGURE 22

FIGURE 23

Figure 23 is a view of the dolly rollover test. Dolly speed is 30 mph, which provides a spectacular 2 and 1/4 roll. Some of the problems with rollovers are test repeatability and assurance of making the two revolutions required by the contract. Specifically, the action of the suspension during the roll event is very difficult to predict.

In the rollover test the ESV did not land on the front roof panel. Thus the cantilever roof design was not tested and the two-foot inverted drop was a very necessary evaluation. The reason for the canting of the center pillar is quite apparent in Figure 24. The springback of the high strength steel is apparent. Residual intrusion was 3.9 inches versus the specified maximum of 3 inches. This is a structural test only, as dummies cannot be installed.

FIGURE 24

Figure 25 illustrates an overhead view of a 15 mph side pole impact into the center of the front door. Intrusion was limited to 3.4 inches versus the 4 inches allowed. This is one door that was not operational after the test. All others, however, were easily opened. The front occupants were satisfactorily restrained by the side support material. However, the right rear passenger moved more than is desirable.

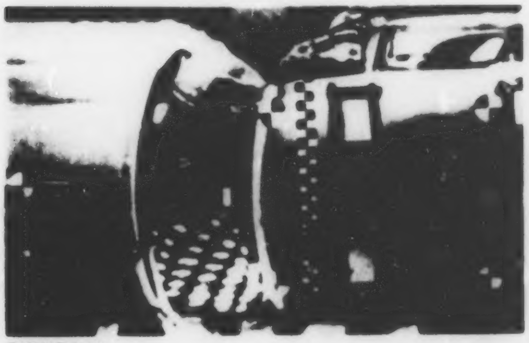


FIGURE 25

Figure 26 shows a 20 mph front barrier impact. Structural deformation was limited to 10 inches. The effect of this abrupt stop is apparent; without air cushions the reactions of the dummies were violent.

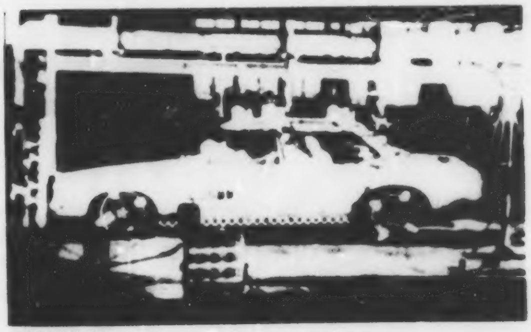
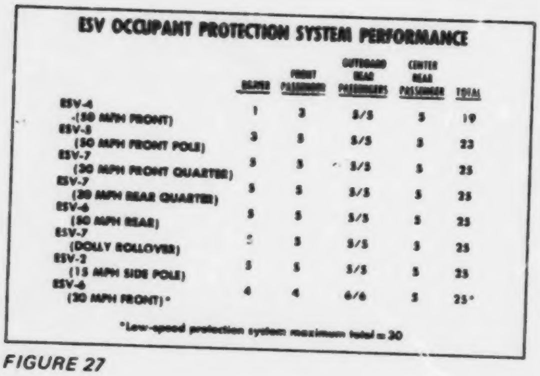


FIGURE 26

Figure 27 is a summary of the test results. It gives an evaluation of the occupant protection system in terms of measured accelerations of the dummies compared to the specified values. The performance rating method for high-speed crashes, which are the first seven tests shown, is based on a score of one point for the five force-related occupant measurements specified in the contract – chest and pelvic g peaks, as well as head, chest and pelvic g pulse duration.

With a score of five points for each seating position, a total of 25 is possible for each high-speed test. With five dummies in each of the seven tests, only three out of 35 did not stay within the specified



ESV OCCUPANT PROTECTION SYSTEM PERFORMANCE

	DRIVER	FRONT PASSENGER	OUTBOARD REAR PASSENGERS	CENTER REAR PASSENGER	TOTAL
ESV-4 (50 MPH FRONT)	1	3	5/5	5	19
ESV-5 (50 MPH FRONT POLE)	3	5	5/5	5	23
ESV-7 (30 MPH FRONT QUARTER)	5	5	5/5	5	25
ESV-7 (30 MPH REAR QUARTER)	5	5	5/5	5	25
ESV-6 (50 MPH REAR)	5	5	5/5	5	25
ESV-7 (DOLLY ROLLOVER)	5	5	5/5	5	25
ESV-2 (15 MPH SIDE POLE)	5	5	5/5	5	25
ESV-6 (20 MPH FRONT)*	4	4	6/6	5	25*

*Low-speed protection system maximum total = 30

FIGURE 27

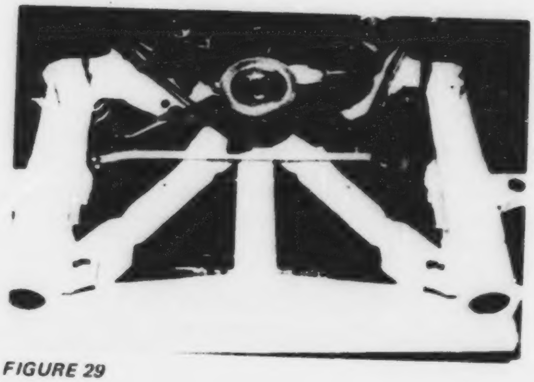


FIGURE 29

limits of acceleration. All three can be explained as a function of less than perfect air cushion performance.

In low-speed crashes, the addition of a head g peak specification permits a total score of 30. The 20 mph fixed barrier test results shown on the last line indicate the need for improvements. Only the outboard rear dummies obtained perfect scores. We have, therefore, adjusted the air cushion sensors to trigger at impact speeds above the 15-18 mph range.

In total, although the exterior of our ESV appears to be taking a beating, particularly in barrier and pole impacts, the name of the game is dummy occupant protection, and this summary indicates that we are not very far from the goal.

Accident Avoidance

This portion of the discussion outlines our approach to chassis design and the result of our accident avoidance testing – with particular emphasis on meeting contract requirements. The concern has been in four basic areas – handling, braking, powertrain and visibility. These have always been design principles, together with durability and serviceability.

The chassis (Figure 28) has a 124-inch wheelbase and a 64-inch tread, front and rear. The frame (Figure 29), made from high strength steel, has a full box section with bracing to accommodate corner impacts. The high lateral acceleration requirements specified in our contract and the weight of the vehicle led to use of an experimental HR 70-15 custom wide-tread, radial ply tire (Figure 30). These were produced by Goodyear to meet the performance specifications described by the lateral force characterizing function shown in Figure 31. The normalized force for the ESV design falls above the level of production tires throughout the full slip angle range.

Present production parts are used for the independent coil spring front suspension (Figure 32), the solid axle four-bar rear suspension (Figure 33), and the pneumatic rear leveling system, with modifications to meet the contract specifications.

The total vehicle understeer coefficient was reduced in comparison with production sedans of a similar size to meet steady state yaw requirements. This was achieved with a 5 percent roll oversteer for the front suspension and a 3 percent roll understeer geometry at the rear.

While there are a great many factors affecting the vehicle understeer, some of those to be considered were weight distribution, roll camber coefficients, front wheel caster, roll stiffness involving roll center

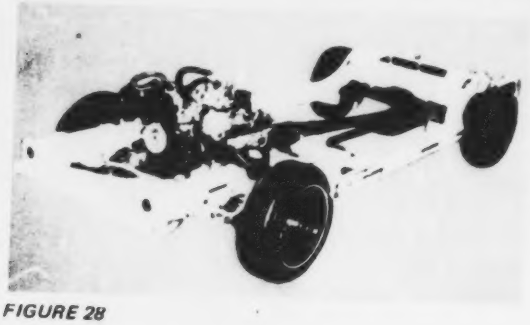


FIGURE 28

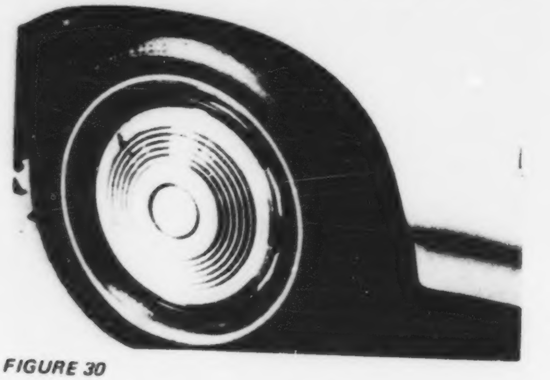


FIGURE 30

heights, the selection of springs and stabilizer bars, and tire performance including lateral forces that have already been discussed, as well as load transfer sensitivity and tire aligning torque properties.

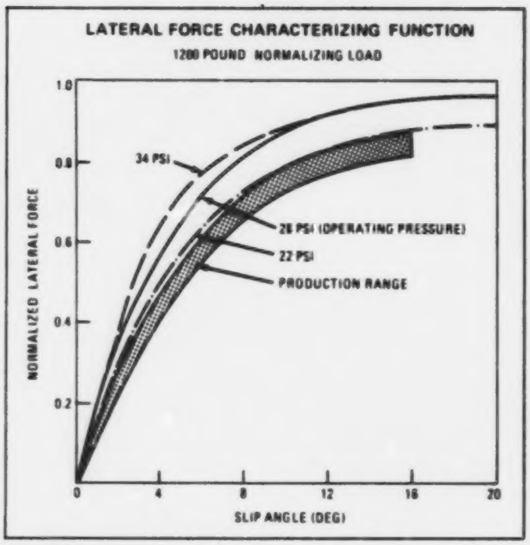


FIGURE 31

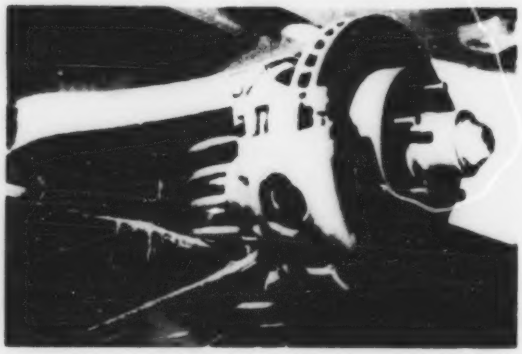


FIGURE 32

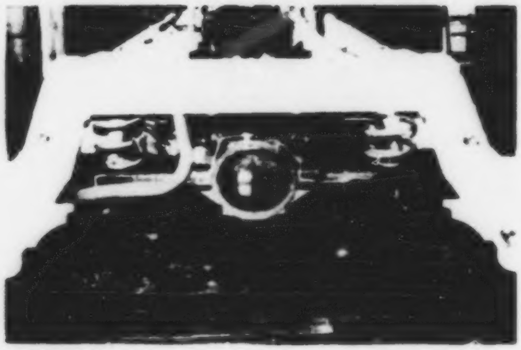


FIGURE 33

The power steering system (Figure 34) was designed to comply with the contract requirement of "power off" steering not more than five times the "power on" wheel torque, by adding an electrohydraulic back-up pump. With no primary power steering pump output, the back-up pump provides the power necessary for normal power steering. The ratio of the variable ratio steering gear changes from 16.4 on center to 14.2 at full turn.

FIGURE 34

In testing steering, handling and directional stability, the GM design satisfied all the specifications listed in Figure 35. While returnability met the contract at 50 mph, the requirement at 25 mph was not achieved. Low tire aligning torque and the natural damping of the steering system are the significant contributing factors. In actual driving, however, the returnability of the vehicle at all speeds is normal and very acceptable.

STEERING, HANDLING AND DIRECTIONAL STABILITY

- STEADY STATE YAW RESPONSE
- TRANSIENT YAW RESPONSE
- STEERING RETURNABILITY AT 50 MPH
- STEADY STATE LATERAL ACCELERATION
- CONTROL AT BREAKAWAY
- PAVEMENT IRREGULARITY SENSITIVITY
- STEERING CONTROL SENSITIVITY
- OVERTURNING IMMUNITY
- LATERAL FORCE INFLUENCE

FIGURE 35

Looking now at some specific test results, the steady state yaw gain (Figure 36) was determined at the 0.4 g lateral acceleration level for speeds of 25, 50 and 70 mph, with yaw rates of 20.1, 10.1 and 7.2 degrees per second respectively. Our data all comes within the specified envelope. The upper curve represents clockwise driving; the lower curve, counterclockwise driving.

Figure 37 shows the contract transient yaw response boundaries. The response resulting from a

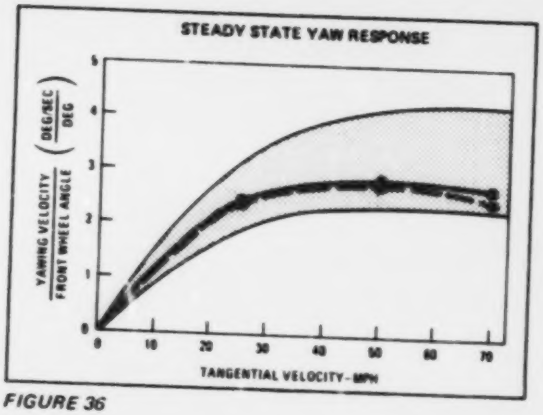


FIGURE 36

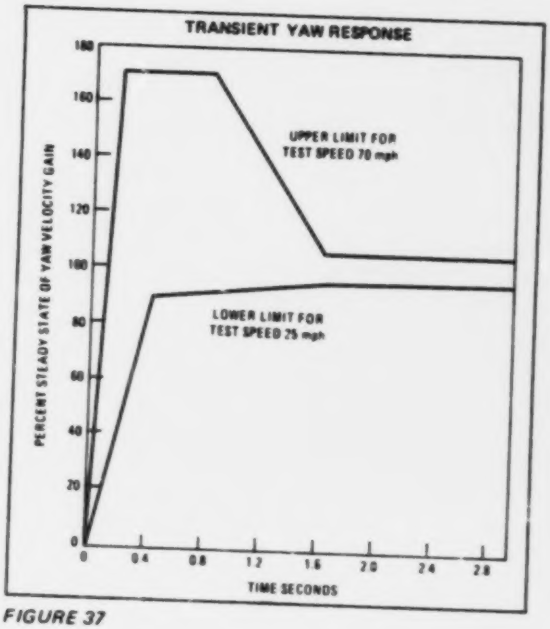


FIGURE 37

step-like steering input was obtained at speeds of 25, 50 and 70 mph. The steering wheel angle required to achieve 0.4 g lateral acceleration at each of the test speeds was determined from the previous steady state yaw response test.

The upper limit, as specified for a test speed of 70 mph, is not exceeded, as Figure 38 shows. The yaw response for a test speed of 25 mph is above the required lower limit shown in Figure 39. The respective response times fell, therefore, within the range of 0.20 to 0.40 seconds.

Figure 40 shows steady state lateral acceleration test results. The maximum fixed control steady state lateral acceleration levels that could be obtained were determined for five tire pressure distributions. Our measured average values in g are all above the

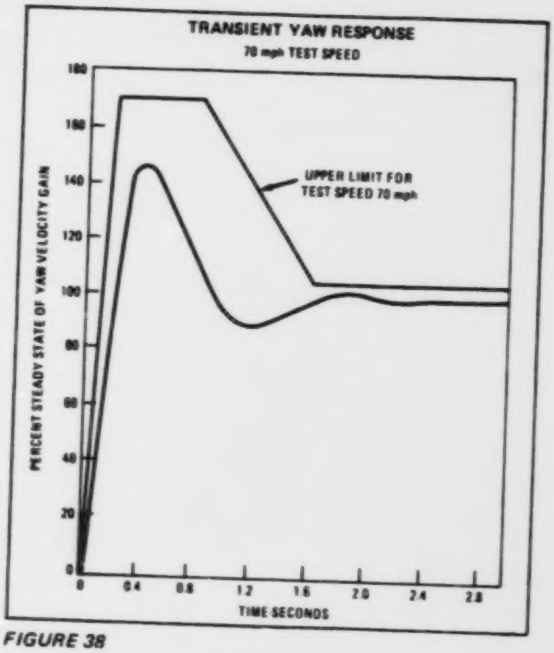


FIGURE 38

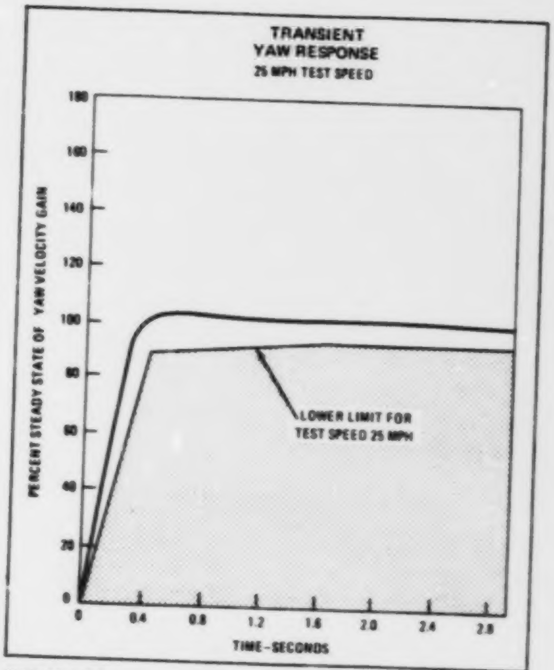
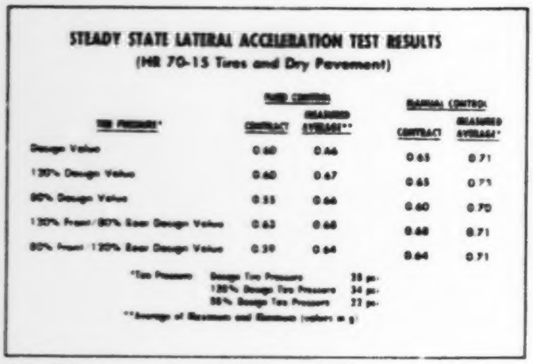


FIGURE 39

specifications. The data for manual control shows a similar achievement. For example, at design tire pressure, the contract requires 0.65 g for manual control. In our test, we averaged 0.71 g, which is approximately 10 percent higher.



STEADY STATE LATERAL ACCELERATION TEST RESULTS
(HR 70-15 Tires and Dry Pavement)

	[illegible]		MANUAL CONTROL	
TIRE PRESSURE*	CONTRACT	MEASURED AVERAGE**	CONTRACT	MEASURED AVERAGE*
Design Value	0.60	0.66	0.65	0.71
120% Design Value	0.60	0.67	0.65	0.71
80% Design Value	0.55	0.66	0.60	0.70
120% Front/80% Rear Design Value	0.63	0.68	0.68	0.71
80% Front/120% Rear Design Value	0.59	0.64	0.64	0.71

*Tire Pressure: Design Tire Pressure 28 psi
120% Design Tire Pressure 34 psi
80% Design Tire Pressure 22 psi
**Average of Maximum and Minimum (values in g)

FIGURE 40

Summing up handling evaluation, our design has received very favorable comments about steering, ride and handling. It is important to keep in mind that handling performance is very complex. The analysis of the total system requires knowledge of the dynamic behavior of each element and the relation of each of them to the whole system. The driver is subject to human variables which cannot be evaluated and tested in the same manner as vehicle systems. The driver's skill also depends on psychological factors, his reaction to his environment, and the feedbacks he received from his vehicle.

Looking now at the brakes, the ESV brake system is a four-wheel disc (Figure 41), four-wheel-lock control system, including a hydraulically actuated power brake, an electro-hydraulic back-up system, and a load sensing brake proportioner (Figure 42). The primary power source for both the steering and the brake system is the power steering pump. In case of a failure in the primary power system, the brake booster and the steering gear will be operated by independent electro-hydraulic back-up pumps. The interconnection of the proportioner with the rear leveling circuit is also shown.

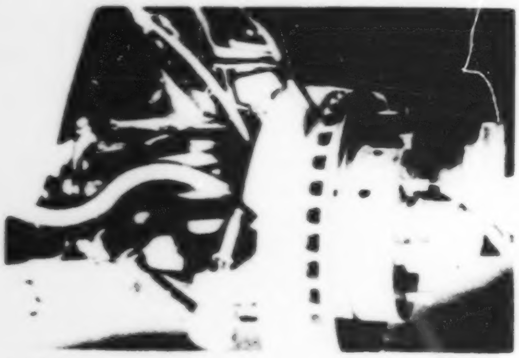


FIGURE 41

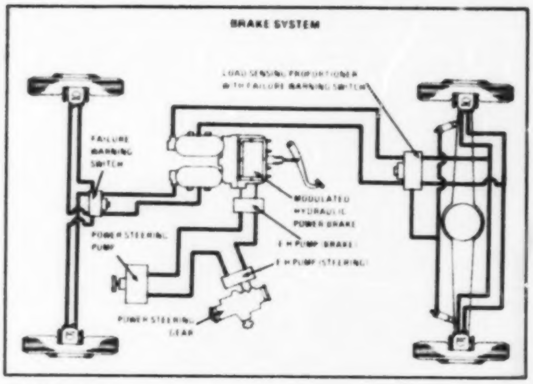
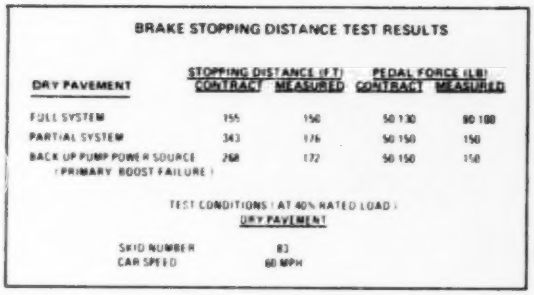


FIGURE 42

Turning now to some of our results from brake development and testing, the design passed all contract specifications (Figure 43). Braking efficiency is not defined in the contract but, by using skid numbers as 100 percent reference, our ESV performs well above 80 percent on dry and wet pavement.

Dry pavement stopping distance test results indicate the effectiveness of the system. The operation with a partial system, for instance, resulted in a stopping distance of 176 feet, compared to 343 feet as specified in the contract.



BRAKE STOPPING DISTANCE TEST RESULTS

	STOPPING DISTANCE (FT)		PEDAL FORCE (LB)	
DRY PAVEMENT	CONTRACT	MEASURED	CONTRACT	MEASURED
FULL SYSTEM	155	150	50 130	80 100
PARTIAL SYSTEM	343	176	50 150	150
BACK UP PUMP POWER SOURCE (PRIMARY BOOST FAILURE)	268	172	50 150	150

TEST CONDITIONS (AT 40% RATED LOAD)
DRY PAVEMENT

SKID NUMBER 83
CAR SPEED 60 MPH

FIGURE 43

Now consider the ESV powertrain design. The powerplant is a 362 cubic inch V-8 gasoline internal combustion engine. The engine block, heads, and intake manifold are made from aluminum. It has an 8.1 to 1 compression ratio and a 4-barrel carburetor (Figure 44).

The basic emission controls consist of an air injection reactor (A.I.R.), preheated intake air, and exhaust gas recirculation system (EGR), an electronic unitized ignition system, transmission controlled spark, and a closed positive crankcase ventilation system (PCV).

A production modified propeller shaft with two universal joints (Figure 45) connects the three-speed

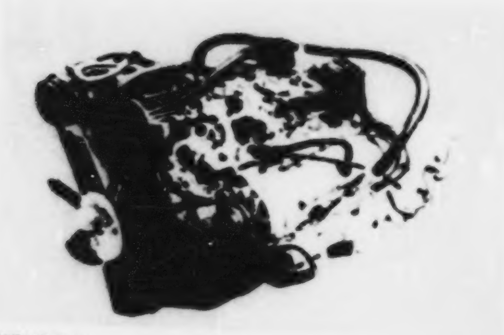


FIGURE 44

FIGURE 45

Hydra-Matic transmission with the rear axle. The yoke of this shaft at the transmission end has been lengthened by 3 inches in order to stay engaged with the transmission output shaft while the engine moves forward during the first period of a high-speed impact.

The fuel tank is made from sheet metal and mounted over the rear axle. The single exhaust system is conventional and constructed from stainless steel.

High vehicle weight, plus the current limited availability and economics of a lightweight engine within General Motors, determined the vehicle performance. Acceleration from 30 to 70 mph in 12 seconds was not achieved. Our best time was 14.5 seconds. On the other hand, the design will meet fuel economy requirements by cruising 285 miles at 60 mph on 23 gallons of gasoline, which is one full tank.

In connection with engine performance testing, it should be noted that the curb weight, for this size of a vehicle, is excessive. Testing per contract includes in addition 600 pounds or 60 percent loading.

Figure 46 illustrates the performance of the emission control system. The vehicle conforms to the 1973 U.S. Federal exhaust emission standards.

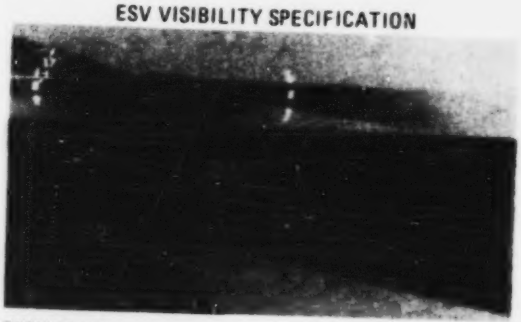
With respect to visibility and vision, a low hood profile and a single, pivoted driver seat, without fore and aft seat adjustment, enable the vehicle to comply with the visibility specifications. The 8-degree down forward vision angle and the 8-degree rear vision arc both intercept the ground line within about one car length.

EXHAUST EMISSION TEST RESULTS
(grams per mile)

	HC	CO	NOx
1973 U.S. FEDERAL STANDARDS	3.4	39.0	3.0
MEASURED	2.1	28.0	2.4

FIGURE 46

Figure 47 shows the improved vision achieved by eliminating the pillars at the sides of the windshield and by decreasing the width of the quarter pillars. The measured horizontal field of view through the inside mirror is 34 degrees, which exceeds the 24-degree contract requirements, as shown by the shaded sector. Very good rear visibility has been achieved without the complexity of a periscopic system.



ESV VISIBILITY SPECIFICATION

FIGURE 47

Figure 48 shows the adjustable brake pedal mechanism that was necessary to provide for the range of leg lengths between the 5-foot-tall woman and the 6-foot 2-inch man. A similar mechanism was used for the accelerator pedal. This unit uses an electro-motor to move both pedals, synchronized by a flexible interconnecting drive cable.

The efforts of the General Motors ESV group have been to develop a car that meets contract specifications. This has been achieved with minor exceptions. There are, however, some questions of practicability which should be seriously studied and considered.

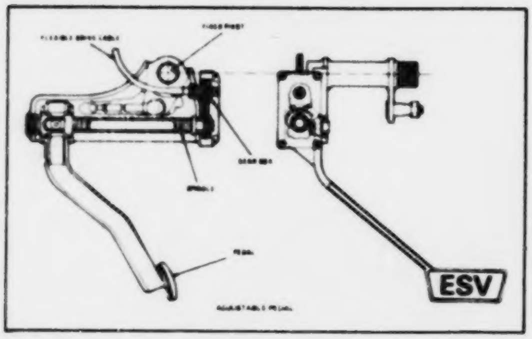


FIGURE 48

One such factor is system complexity and associated cost/value relationships.

Restraint System

The initial selections of design approaches to the occupant protection system for the ESV were based upon these rules:

1. The system would be occupant-passive — requiring no voluntary or precautionary action by the occupants to make it function.
2. There would be two speed levels of occupant protection: low speed under 20 mph, and high speeds ranging above this value.
3. For low-speed impacts, the system would be essentially static — providing acceptable occupant restraint and control from a system already in place.
4. For high-speed impacts, a dynamic element would be added — deploying on impact to provide a much higher level of occupant restraint and control.
5. The low-speed system, in addition to functioning in low-speed impacts, would supplement the high-speed system whenever it is deployed.

For the low-speed subsystem, trim-faced energy absorbing foam mounted on crushable metal substructures was selected (Figure 49). This was a practical approach based on our knowledge of the materials involved. This knee panel structure (Figure 50), for example, fabricated from honeycomb-type material, has predictable crush characteristics and is readily available. For experimental development, such materials can be easily modified to provide the needed crush force. However, they are costly for production applications.

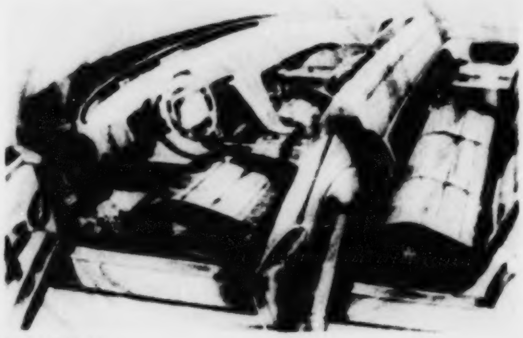


FIGURE 49

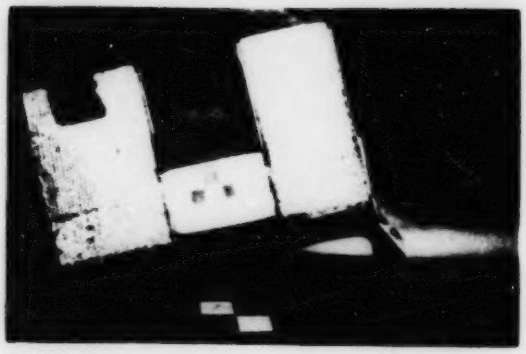


FIGURE 50

Many design approaches were considered in selecting the deployable subsystem for high-speed impacts. These included a net or blanket system, restraining belts, crushable panels, and air cushions inflated by either a chemical gas generator or stored compressed gas.

The approach selected for the high-speed subsystem was the deploy-on-impact air cushion (Figure 51). An important factor in this decision was the fact that every component of the air cushion configuration was capable of redesign or refinement. This proved to be a very important and necessary advantage when the test program was started.

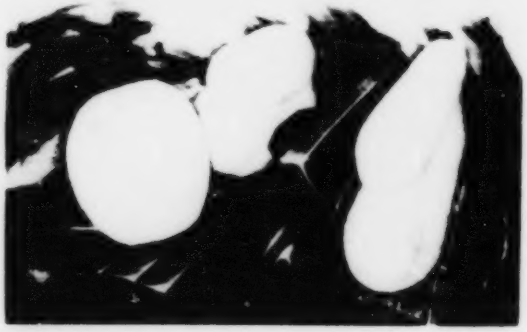


FIGURE 51

A dual choice was made in selecting energy sources for air cushion inflation. The cushions for the right front and rear seat occupants are inflated with compressed gas stored in pressure vessels. Development programs were already under way within GM to aid in developing this design. In the driver's position, we needed a self-contained system that would fit within the steering wheel hub. Accordingly, a gas generator was selected for inflating the air cushion at this location. The hot exhaust gas can be cooled to a safe temperature because its volume is small.

This report includes results of our final prototype program, since late 1971. This program involved final design changes and parts modification. Prototype components were sled tested for final tuning and then installed in prototype vehicles for validation testing.

The analysis for the low-speed subsystem at 20 mph is based upon the Cornell mathematical model of the automobile crash victim (Figure 52). It includes the anthropometric properties of the occupant and the crush properties of the windshield, instrument panel, lower instrument panel and toe board impact targets. These energy absorbing substructures are designed to accommodate a mixture of dummies, ranging from the 5th percentile female to the 95th male.

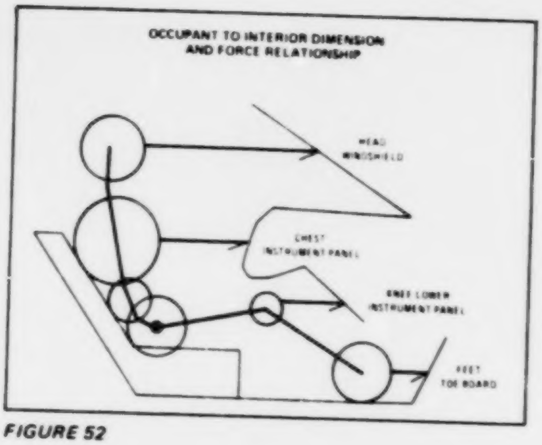

OCCUPANT TO INTERIOR DIMENSION
AND FORCE RELATIONSHIP
HEAD
WINDSHIELD
CHEST
INSTRUMENT PANEL
KNEE LOWER
INSTRUMENT PANEL
FEET
TOE BOARD

FIGURE 52

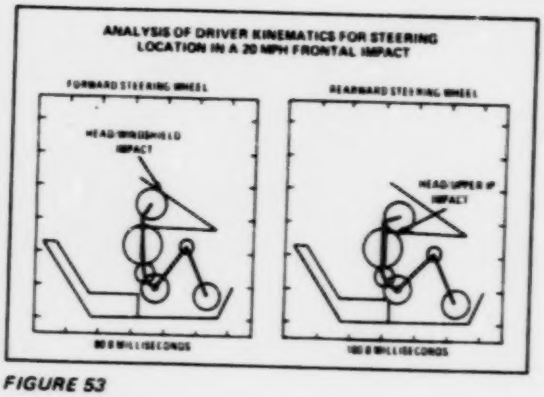

ANALYSIS OF DRIVER KINEMATICS FOR STEERING
LOCATION IN A 20 MPH FRONTAL IMPACT
FORWARD STEERING WHEEL
HEAD/WINDSHIELD
IMPACT
80.0 MILLISECONDS
REARWARD STEERING WHEEL
HEAD/UPPER IP
IMPACT
100.0 MILLISECONDS

FIGURE 53

As an example of the value of modeling, Figure 53 shows an experimental ESV interior configuration trade-off study with a 50th percentile male General Motors hybrid dummy and a forward mounting position for the steering wheel. In this position, the head impacts the windshield at 80 msec. Relocating the wheel to a more rearward position, the head misses the windshield and impacts the upper instrument panel surface at 100 msec. We selected this design for the 50th percentile male. However, the 95th male impacts the windshield, but his head mass is larger and produces a low g level.

For air cushion restraint systems, General Motors has developed a computer program to supplement the Cornell model. It simulates the deployment of the air cushion and occupant kinematics. We determined the placement and sizing of the air cushions for higher speeds in conjunction with the crushable energy absorbing substructures developed for lower speeds with this program.

For example, Figure 54 shows a computer simulation of an air cushion restraint system for the rear occupants. The figure illustrates the deployment of a head and chest cushion at 25 msec. It shows the head is about to contact the head cushion, the chest is embedded in the chest cushion, and the knees are just contacting the knee panel.

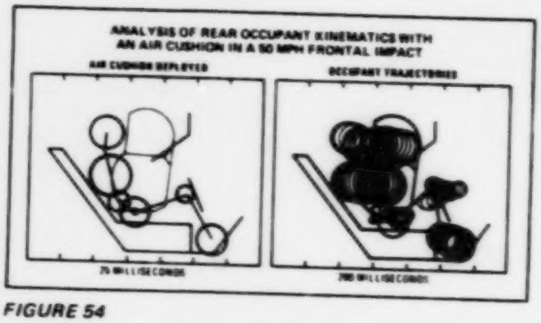

ANALYSIS OF REAR OCCUPANT KINEMATICS WITH
AN AIR CUSHION IN A 50 MPH FRONTAL IMPACT
AIR CUSHION DEPLOYED
25 MILLISECONDS
OCCUPANT TRAJECTORIES
200 MILLISECONDS

FIGURE 54

The engraving-like figure on the right of Figure 54 shows the trajectories of the dummy's head, chest, H-point, knees and feet, plotted every 10 msec. for the first 200 msec of a crash. It shows the head and chest have penetrated the air cushion and the knees have stroked the knee panel. This is acceptable kinematic behavior with our rear air cushion system.

Figure 55 illustrates one of our static crush tests, in this case a knee panel for the right front passenger.

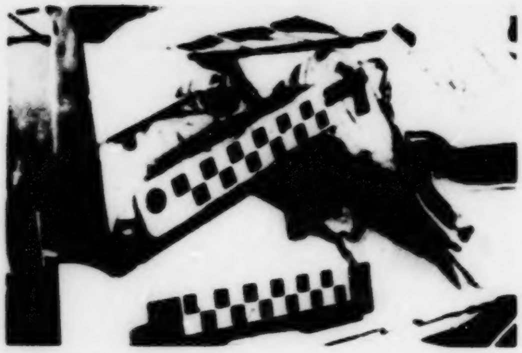


FIGURE 55

The femur loads and knee displacements are recorded during the crush test to evaluate the restraint force properties for the knee panel design.

In Figure 56 the rear compartment is shown before static deployment of the air cushion. It is stowed within the credenza-like trim surface in front of the passengers.

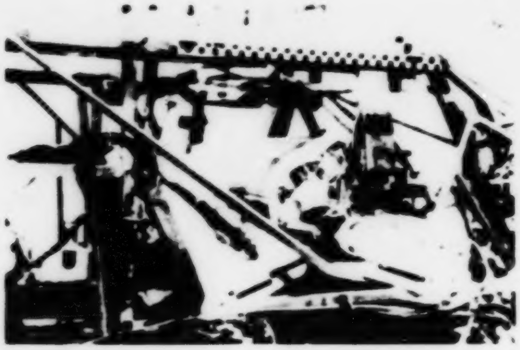


FIGURE 56

Figure 57 shows that the air cushion has deployed properly by breaking through the credenza trim. Tests also verified the compressed gas pressure 3500 psi in this case, evaluated the rate of deployment, and checked strength and durability of the air cushions and related hardware.

FIGURE 57

Our final configuration for the driver restraint system is shown in Figure 58. It includes an air cushion deployed from the steering wheel, in series with an energy absorbing column, crushable instrument panel, and crushable knee panels to control the driver behavior. The seat translates forward in all seating locations to maintain the driver's attitude relative to the restraint system.

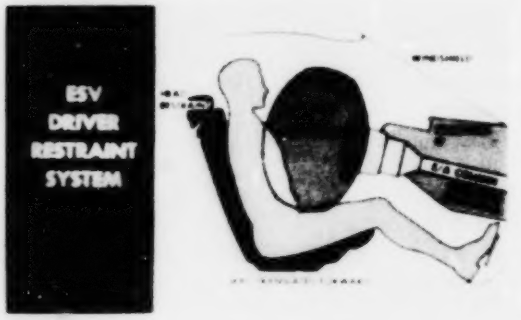


FIGURE 58

Figure 59 illustrates the right front passenger restraint system, with a head/chest air cushion, in which the two compartments are formed by a vented baffle. It also shows a crushable instrument panel and a crushable knee panel. There is a head restraint for occupant rebound and rear impacts in all seating locations.

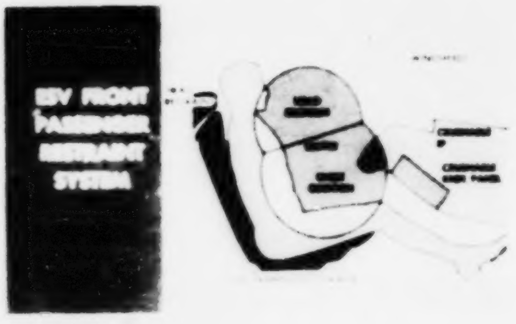


FIGURE 59

The restraint system for the rear passengers (Figure 60) consists of a two-compartment air cushion which deploys from the credenza. The credenza is crushable for low-speed impacts, and the knee panels stroke forward to control the rear passengers' orientation relative to the restraint system.

Figure 61 tabulates the front compartment occupant protection test data for the frontal pole impact.

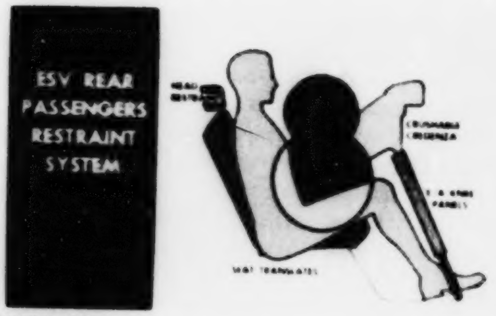


FIGURE 60

ESV 5 50 MPH POLE – FRONT SEAT OCCUPANTS

			DRIVER		PASSENGER	
	INJURY CRITERIA	SPECIFICATION	MET	NOT MET	MET	NOT MET
HEAD	PEAK (G)	*	(92)		(72)	
	DURATION (MSEC)	3 (>80 G)		0	0	
CHEST	PEAK (G)	100 G	80		57	
	DURATION (MSEC)	3 (>60 G)		16	0	
PELVIS	PEAK (G)	100 G	72		58	
	DURATION (MSEC)	3 (>60 G)		3.3	0	
FEMUR	LEFT (LB)	1400		2540	880	
	RIGHT (LB)	1400		2150		1800

*NO SPECIFICATION FOR HEAD PEAK G

FIGURE 61

The contract specifications are in the second column, and the test data in the third column. As examples, the driver's head shows 92 g, the chest 80 g, and the pelvis 72 g. The pelvis duration is 3.3 msec, marginally over the contract, within dummy test repeatability. The durations of the head and chest exceed the contract because the air cushion pressure is too low in this test, and the femur loads are high because the knee panel is too stiff.

The passenger's head, chest, pelvis and femur values meet the contract specifications. The left femur load is high because the right knee panel support is too stiff. This can be reduced by selecting lower crush rate material.

The next table (Figure 62) shows occupant protection test data for the rear passengers. All values meet the contract, except for the center passenger's right femur and the right passenger's chest duration, which is regarded as within dummy test repeatability. Subsequent component tuning has been incorporated to reduce these values.

A great deal of experience in designing and developing restraint systems to meet the requirements of our contract was gained in the past two years of our study, especially in translating results into practice.

ESV 5 50 MPH POLE – REAR SEAT OCCUPANTS

			LEFT		CENTER		RIGHT	
	INJURY CRITERIA	SPECIFICATION	MET	NOT MET	MET	NOT MET	MET	NOT MET
HEAD	PEAK (G)	*	(58)		(50)		(68)	
	DURATION (MSEC)	3 (>80 G)	0		0		0	
CHEST	PEAK (G)	100 G	53		57		72	
	DURATION (MSEC)	3 (>60 G)	0		0			14
PELVIS	PEAK (G)	100 G	58		53		47	
	DURATION (MSEC)	3 (>60 G)	0		0		0	
FEMUR	LEFT (LB)	1400	1230		1120		1000	
	RIGHT (LB)	1400	1240			1820	1010	

*NO SPECIFICATION FOR HEAD PEAK G

FIGURE 62

Conclusions

Our goal in the ESV program has been to build a car that meets the contract specifications, and not to attempt to evaluate these requirements. However, this program is only a part of a continuing effort within General Motors to explore possible ways to improve the area of highway safety which relates to the vehicle itself. With the conclusion of this contract, the talents of the engineers and designers can be utilized with more flexibility to optimize and develop for production such systems as appear to be of real value.

In the area of vehicle handling, the technology is well established. We can produce any desired characteristic, anywhere from the traditional limousine to the typical sports car. We have little argument with the contract specifications in general; in fact, many current production cars meet them. But we question whether the high lateral acceleration specification is required for a family sedan. Also, meeting the specifications may not necessarily insure good handling.

In the braking system, the main problem again is not in physically producing the specified performance; it is rather in determining which compromise will provide the combination of cost and utility that the consumer can afford and utilize. For example, the amount of redundancy we have incorporated in the braking system may be difficult to justify.

The major problem area of the entire vehicle is certainly that of crashworthiness. Our test results indicate that the contract specifications can almost be met — except for weight — but we should remember that the correlation between performance of dummies in controlled tests and the injury potential in real life collisions is a subject well beyond the scope of the ESV program.

The original contract weight goal of 4000 pounds, plus or minus 200, has not proved attainable. This is true even though substantial weight reductions were achieved in many ways — by efficient use of such materials as aluminum and high strength steel; by designing the entire vehicle with closely controlled crush distances; and by changing from the heavy 10 mph bumper system to the lighter, less complicated 5 mph bumper system.

However, before further weight reduction is attempted, it is advisable to scrutinize the specifications. For example, because a seat belt system could not be considered "passive" in contract terms at the time the design decision had to be made, no serious analysis was made within the program to see what influence the choice of a belt restraint system might have had on the total vehicle, including its weight.

An air cushion system was chosen to comply with the contract requirement for a "passive" restraint, and the experimental system we developed has performed satisfactorily in several tests. However, the system is indeed experimental, and its reliability — in regard to misfiring or non-firing, for example — is still uncertain. Also, its noise level during deployment needs further consideration.

While all these problems most likely can be resolved eventually, there is one fundamental difficulty. To stop the occupants' motion, an energy absorber is needed, not a spring. And the air cushion is basically a spring, although it can be given some damping effect through control of inflation and deflation. On the computer, at least, the success of a given air cushion system is extremely sensitive to this damping control. However, the variety and number of tests necessary to check out this result was too great to be part of this program.

It appears that the necessary characteristics of the front structure for a 20 mph barrier capability without any restraint at all are different from the ideal structure when an air cushion system is used. In future studies of vehicle concepts, therefore, the choice of restraint systems deserves the keenest attention.

In conclusion, although our efforts did not result in a car feasible for production and practical for the consumer, the ESV program has been a worthwhile study. Even so, its main value may be found in all the questions it raises that are as yet unanswered.

UNITED STATES
THE FORD MOTOR COMPANY
ESV PROGRAM

MR. STEWART M. FREY
Chief Planning and Research Engineer

ESV PROGRAM
Ford

Ladies and Gentlemen:

The Ford ESV program has been divided into two phases: the systems prove-out phase and the prototype phase. At the time of the Stuttgart Conference, we were near the completion of our systems prove-out, subsequently concluded last December. Fourteen complete vehicle crash tests were conducted during this phase to refine our systems design.

We are now well into the prototype phase, which will include the crash testing of seven complete prototype vehicles. Two of these tests have already been completed. In addition, we are progressing on schedule with the construction of the fully equipped prototype car for delivery to DOT in December of this year.

The exterior and interior styling and design for the prototypes were completed in January and March, respectively. You will have an opportunity to see a full scale model of the prototype vehicle in the Ford corporate exhibit area at Transpo. Our ESV chassis is displayed as part of the DOT exhibit.

Our presentation today consists of the following six parts: First I will describe Ford's approach to the design of the ESV, then recap its design features. Third, I will discuss weight projections in comparison to a production vehicle. Fourth, I will show films of three recent crash tests and discuss the results. Next, I will describe the interior and exterior design of the ESV, and conclude the presentation with comments on our views as to some important aspects of the present program.

FORD ESV PROGRAM

- FORD APPROACH
- VEHICLE DESIGN
- WEIGHT PROJECTIONS
- TEST RESULTS
- INTERIOR AND EXTERIOR DESIGN
- CONCLUSION

FORD APPROACH

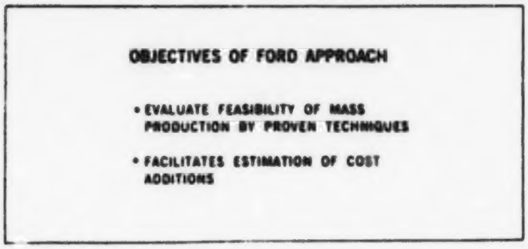
OVERALL VEHICLE CONCEPT

MODIFY DESIGN OF CURRENT 4-DOOR SEDAN TO:

- COMPLY WITH ALL FORD PRODUCT ACCEPTANCE STANDARDS
- COMPLY WITH ALL APPLICABLE FMVSS STANDARDS AND EMISSION CONTROL STANDARDS

As we outlined at the last Conference, our approach was to start with a standard production car and modify the design as necessary in an attempt to meet the objectives of the program. In addition, the design was to comply with all our internal product acceptance standards and also all applicable current motor vehicle safety standards and emission control standards.

At the meeting in Stuttgart, we told you that it was our hope, that by following this approach we would be able to come closer to developing an ESV



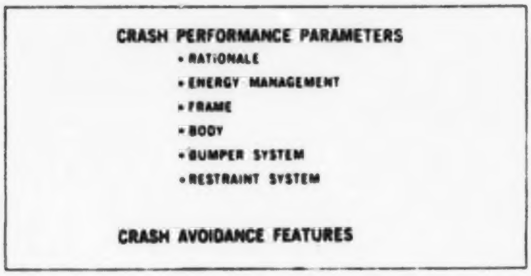
OBJECTIVES OF FORD APPROACH

- EVALUATE FEASIBILITY OF MASS PRODUCTION BY PROVEN TECHNIQUES
- FACILITATES ESTIMATION OF COST ADDITIONS

that was capable, to a large degree, of being mass produced by proven techniques, thus we would be better able to estimate the costs of building an ESV.

Based on results to date, we must report that we have not been able to achieve this goal. However, our approach had the advantage of company-wide participation in the project, which enabled us to clearly determine the differences in the design and fabrication of the ESV and its components as compared to a current production vehicle.

VEHICLE DESIGN



CRASH PERFORMANCE PARAMETERS

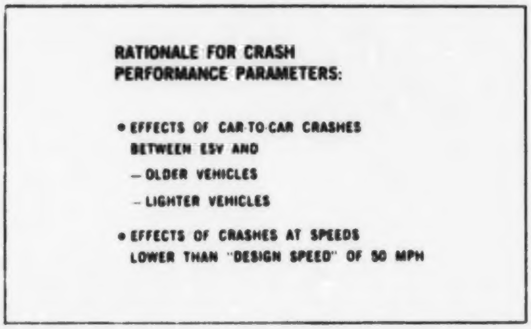
- RATIONALE
- ENERGY MANAGEMENT
- FRAME
- BODY
- BUMPER SYSTEM
- RESTRAINT SYSTEM

CRASH AVOIDANCE FEATURES

We will now recap the design of the major subsystem of the Ford ESV. At this point, we would like to stress again the fact that our approach has been to put primary emphasis on improved occupant protection to better understand our design approach. Let us now review the design rationale, the energy management between the frame and body, the frame design, the body front end design, the bumper system and the passenger restraint system.

A description of the crash avoidance features of the ESV will conclude the vehicle design section.

Our objective was to design the ESV for improved occupant protection over a wide range of impact speeds; therefore, some degree of collapse under crash must be provided. For example, this approach suggested a front end design that collapses progressively under increasing force levels.



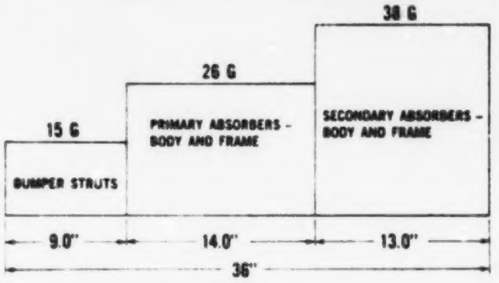
RATIONALE FOR CRASH PERFORMANCE PARAMETERS:

- EFFECTS OF CAR-TO-CAR CRASHES BETWEEN ESV AND
  - OLDER VEHICLES
  - LIGHTER VEHICLES
- EFFECTS OF CRASHES AT SPEEDS LOWER THAN "DESIGN SPEED" OF 50 MPH

In addition to providing some degree of collapse and, thus, some energy absorption at lower speeds, this technique will presumably reduce the impact forces imparted to the older and lighter vehicles that might be struck by the ESV.

ENERGY MANAGEMENT

THEORETICAL CRUSH DISTANCE VS COMPARTMENT G LEVELS AT 50 MPH CRASH



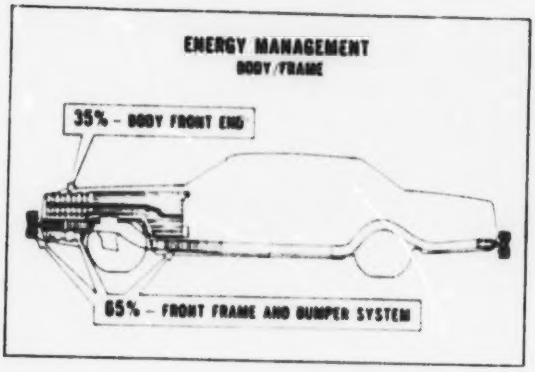
38 G
26 G
15 G
PRIMARY ABSORBERS - BODY AND FRAME
SECONDARY ABSORBERS - BODY AND FRAME
BUMPER STRUTS
9.0"
14.0"
13.0"
36"

This diagram depicts the theoretical G-levels of the 3-step energy absorption system. Wheelbase and front overhang had to be increased three inches over a production Ford to provide for 36 inches of crush. This distance provided acceptable limits on engine intrusion into the firewall.

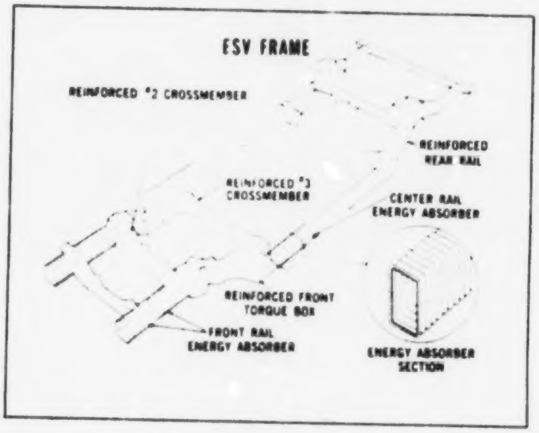
The front end was designed to sustain increasingly higher G-levels, from 15 g to 26 g to 38 g. This offered greater predictability of collapse. It also is hoped that this reduces crash loads at lower impact speeds.

The initial front end design had a 9 to 1 split for frame and body energy absorption respectively. This later was revised to 65% frame and 35% body in order to reduce frame rigidity and raise the center of impact resistance closer to the vehicle's center of gravity.

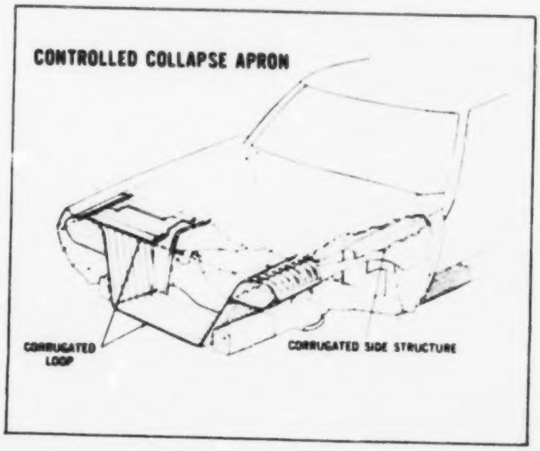
The lower frame forces resulted in lower bumper bar loads and improved the ability to cope with pole impact forces. The upward shifting of the center of resistance line reduced the tendency for the rear end to kick-up during impact.


ENERGY MANAGEMENT
BODY/FRAME
35% – BODY FRONT END
65% – FRONT FRAME AND BUMPER SYSTEM

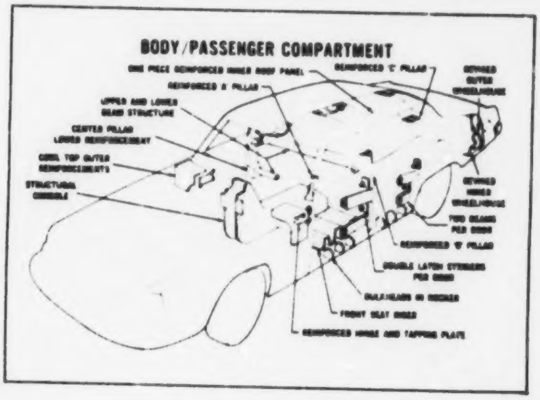
The general configuration of the ESV frame is similar to the current full-size Ford frame.


ESV FRAME
REINFORCED #2 CROSSMEMBER
REINFORCED REAR RAIL
REINFORCED #3 CROSSMEMBER
CENTER RAIL ENERGY ABSORBER
REINFORCED FRONT TORQUE BOX
FRONT RAIL ENERGY ABSORBER
ENERGY ABSORBER SECTION

To achieve the 65% energy absorption, convoluted sections were added ahead of the front spring pockets and on the side rails. The torque box, the frame center rail sections and crossmember were reinforced to withstand the higher force levels without bending.

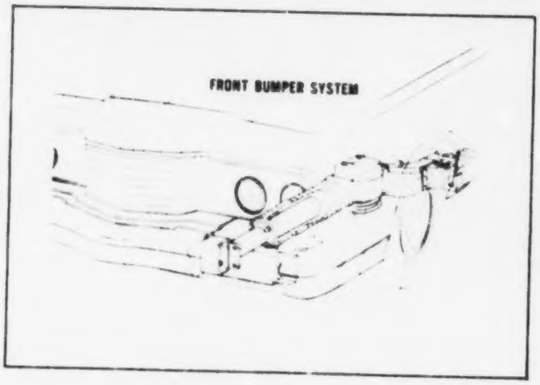

CONTROLLED COLLAPSE APRON
CORRUGATED LOOP
CORRUGATED SIDE STRUCTURE

The body front end shown here was designed to absorb 35 percent of the total energy through a structure which we describe as a "controlled collapse apron." It features corrugated sheet metal integrated into the apron. The forward section with transverse corrugations forms a complete hoop after the top section has been bolted-on. The bolt-on feature facilitates engine decking. Side aprons are married to the firewall with sufficient structure for load support.


BODY/PASSENGER COMPARTMENT
ONE PIECE REINFORCED INNER ROOF PANEL
REINFORCED 'C' PILLAR
REVISED OUTER WHEELHOUSE
REINFORCED A PILLAR
UPPER AND LOWER BEAM STRUCTURE
CENTER PILLAR LOWER REINFORCEMENT
COWL TOP OUTER REINFORCEMENTS
STRUCTURAL CONSOLE
REVISED INNER WHEELHOUSE
TWO BEAMS PER DOOR
REINFORCED 'B' PILLAR
DOUBLE LATCH STRIKERS PER DOOR
BULKHEADS IN ROCKER
FRONT SEAT RISER
REINFORCED HINGE AND TAPPING PLATE

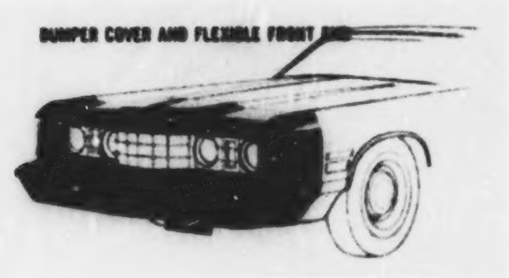
This slide shows the major structural components of the passenger compartment intended to improve compartment integrity under various crash modes. The basic principle, of course, is to effectively create a "roll-cage" for the compartment.

The structures shown here, along with the controlled collapse apron shown in the previous slide, represent the principal body changes made to meet the objectives for passenger compartment integrity.


FRONT BUMPER SYSTEM

The front bumper system is depicted on this schematic drawing. The bumper face bar is supported by two hydraulic struts attached to the frame.

The face bar, fabricated of a high strength steel, incurs minimum plastic deformation during a pole test and transmits the impact forces directly to the frame. The hydraulic struts are velocity sensitive and exhibit a low reaction force level at 10 mph for the no-damage feature. They provide a higher reaction force level at 50 mph for more effective energy dissipation during the 9" bumper stroke.

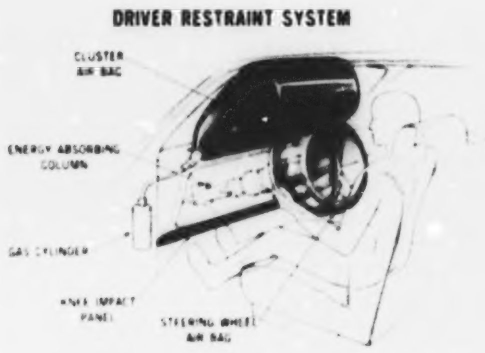


BUMPER COVER AND FLEXIBLE FRONT END

The bumper face bar is covered with a urethane plastic. This cover is continued rearward to close the gap between the frame and the bumper. The urethane has the ability of flexing and then returning to its original shape without damage after bumper impacts, not exceeding 10 mph.

The shaded portions of the fenders and hood are also made of flexible material and are designed to comply with the 10 mph no-damage requirements. Tests are currently underway to prove feasibility.

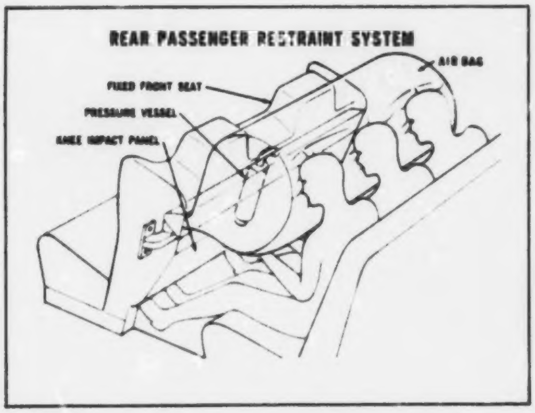
The rear bumper construction is essentially the same with the exception that the face bar is made from aluminum and the supporting struts are smaller and lighter than those used in the front.



DRIVER RESTRAINT SYSTEM

The design and development of the driver restraint system presented the greatest challenge because of severe space limitations and the resulting complexity of a multiple component arrangement. Ford's approach employs one air bag in the steering wheel, a second bag in the cluster, and a controlled collapse steering column. A knee panel augments the system to help prevent submarining.

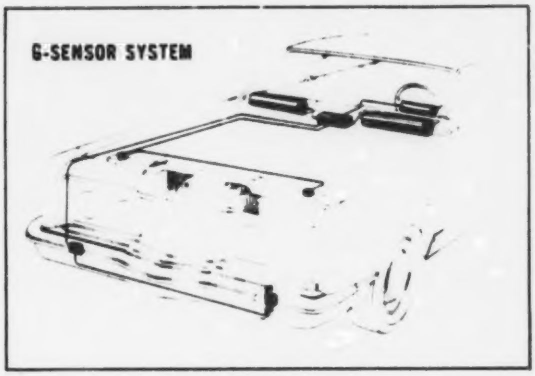
For optimum performance, a rather flat column angle with a close coupled steering wheel is required.



REAR PASSENGER RESTRAINT SYSTEM

One common air bag is used for all rear seat occupants. It is contained, together with its diffuser and pressure vessel, in the fixed front seat back. The seat back is supported by transverse beams between the B-pillars. A knee impact panel is mounted below the air bag.

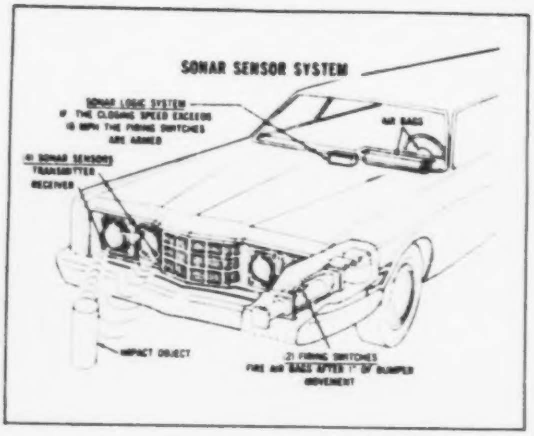
The front passenger is provided with a similar system except for the smaller size of the air bag.



G-SENSOR SYSTEM

All air bags are activated by g sensors mounted on the bumper face bar. The sensors are calibrated to activate at an impact of more than 15 mph and will trigger the air bag system in about 3 milliseconds after impact.

A second set of g sensors is mounted on the radiator support to inflate the bags in the event that the bumper is not involved in the initial impact, or if the bumper sensors fail to operate.



A sonar sensing system was one of our candidates for the air bag activation. The system consisted of two sets of transmitters and receivers mounted in the grille. When a specified closure speed is detected with an obstacle five feet in front of the vehicle, the air bag switch is armed. Deployment of the air bag is then triggered by a bumper movement switch.

The much less complex bumper mounted g sensors were our final choice since they proved capable of deploying the air bags at a speed comparable to the sonar system.

CRASH AVOIDANCE FEATURES

BRAKING

- FRONT DISC BRAKES WITH SEMI-METALLIC LININGS
- 12" REAR DRUM BRAKES WITH ORGANIC LININGS
- HYDRAULIC POWER BRAKE BOOSTER WITH RATIO CHANGER
- REAR WHEEL SKID CONTROL

As to crash avoidance, we will attempt to meet the DOT objectives for brake system performance by modifying the design of proven brake system hardware. Our present design uses front disc brakes with semi-metallic linings and twelve inch rear drum brakes with organic linings.

To meet the requirement for stopping with booster power-off or with partial system failure, we have provided an hydraulic brake booster featuring a ratio change during the power-off mode installed with a 4 x 2 redundant brake system. A rear wheel skid control system is also included.

CRASH AVOIDANCE FEATURES

HANDLING AND STEERING

- INCREASE IN TIRE AND RIM SIZES
- STRENGTHENED SUSPENSION
- STRONGER STEERING LINKAGE

Meeting the handling and steering performance criteria will require the following: wider wheels and tires to meet lateral acceleration limits; the front and rear suspension retuned and strengthened; and the steering linkage reinforced to carry the added force levels imposed on the system by the added vehicle weight.

WEIGHT PROJECTIONS

1973 PRODUCTION BASELINE VEHICLE	**4300#**
WEIGHT ADDITIONS – FORD ESV	
• BODY	340
• FRAME	320
• BUMPER SYSTEM – FRONT & REAR	100
• RESTRAINT SYSTEM	100
• CHASSIS COMPONENTS	140
TOTAL INCREASE (ESV)	**1000#**
PROJECTED FORD ESV CURB WEIGHT	**5300#**

WEIGHT PROJECTION

Based on our current prototype design status, we are projecting an ESV curb weight of 5300 pounds. This represents a base car weight and does not include such options as air conditioning, power windows, etc. The 5300 pounds represent an increase of approximately 1000 pounds over a comparable equipped 1972 Ford production model, or 600 pounds over Ford's maximum ESV contract weight. Not surprisingly, body and frame modifications to achieve the energy absorption and structural integrity objective account for two-thirds of the total weight increase.

VEHICLE CRASH TESTS

TEST (A) – 50 MPH FRONT POLE (PROVE-OUT VEHICLE)

TEST (B) – 50 MPH FRONT BARRIER (PROVE-OUT VEHICLE)

TEST (C) – 50 MPH FRONT BARRIER (PROTOTYPE VEHICLE)

VEHICLE CRASH TESTS

I will now show you film clips of three recent 50 mph frontal crash tests. The pole crash and the first barrier test were still conducted with prove-out vehicles. A prototype vehicle was used in the second barrier test.

The resulting g levels on the occupants will be discussed after the film.

MOVIE SEGMENT – TEST A

50 MPH FRONT POLE
PROVE-OUT VEHICLE

Movie Narration Test A

This 50 mph front pole impact test was a crucial step in our prove-out phase. The transmitting of the pole impact forces through a high strength steel bumper beam to the frameside rails was essential to insure the activation of the energy absorbing systems in an efficient manner. The test was successful. Static pole intrusion was approximately 40 inches, and the one hundred pound bumper beam sustained only two inches of permanent deformation between the left and right frame rails. All air bags deployed were triggered in this case by radiator mounted g-sensors.

After the completion of the nine-inch bumper strut stroke, the front frame absorbers collapsed as designed. The side rail absorbers were compressed with approximately 80% efficiency. Rear end kick-up of the vehicle was modest, indicating that the controlled collapse front apron of the body is capable of absorbing a significant amount of energy in a pole crash by pulling the sides of the structure inside and around the pole. The bottom portion of the apron was compacted by the bumper very similar to a flat barrier crash mode. Both hydraulic bumper struts returned to their extended position after the test.

MOVIE SEGMENT – TEST B

•50 MPH FRONT BARRIER
PROVE-OUT VEHICLE

Movie Narration – Test B

This was the last of our 50 mph flat barrier crash tests conducted during the prove-out phase. The main purpose was to verify the concept of the controlled collapse body apron in combination with a frame of 65 percent energy absorption level. Also, a crash sensing probe was installed in front of the bumper to simulate very early air bag deployment for the driver restraint system. All passenger air bags were still triggered by radiator mounted g-sensors. The bumper struts and the front frame rail absorbers functioned 100 percent as designed, as did the corrugated front apron. However, twisting of the front torque box occurred, which rendered the side rail absorbers only 50 percent effective. The structure was subsequently revised and tested with our prototype, as shown on the next film sequence, Test C.

MOVIE SEGMENT – TEST C

•50 MPH FRONT BARRIER
PROTOTYPE VEHICLE

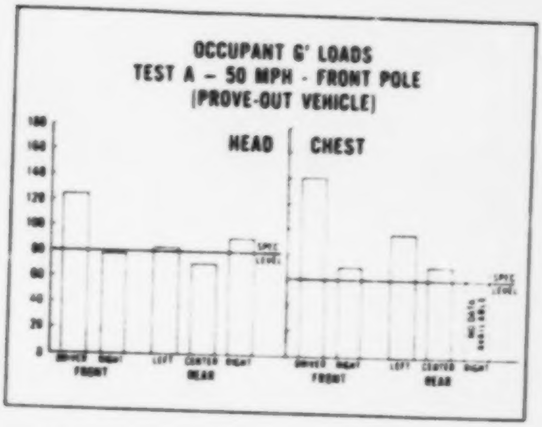
Movie Narration – Test C

This film shows the prototype vehicle in the 50 mph flat barrier crash test. Static crush was 36 inches. Passenger compartment integrity and door retention were satisfactory. Bumper struts, front and side rail absorbers functioned properly. Torque box twisting was eliminated. Activation of air bags for driver and passengers was triggered by bumper mounted g-sensors, giving early deployment and occupant contact. The front fenders detached. But since they are not part of the energy absorbing front apron, this is not considered to be a problem. Passenger compartment deceleration averaged 31 g's.

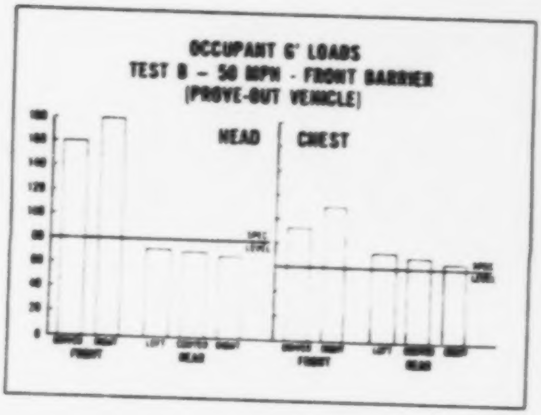
Before discussing the test results, I would like to point out that standard Sierra dummies were used in all our tests.

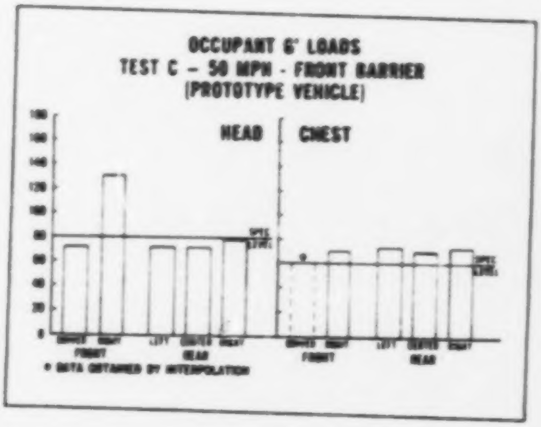
In Test A, the pole crash test, occupant head and chest loads met or were close to meeting the project objectives except for the driver. The driver system at this time was being developed on the Hyge sled facility and the design of the system was still unresolved. Chest loads for the left rear occupant were high due to the rear air bag ripping.

In Barrier Crash B, the driver loads were again extremely high. High head and chest loads on the

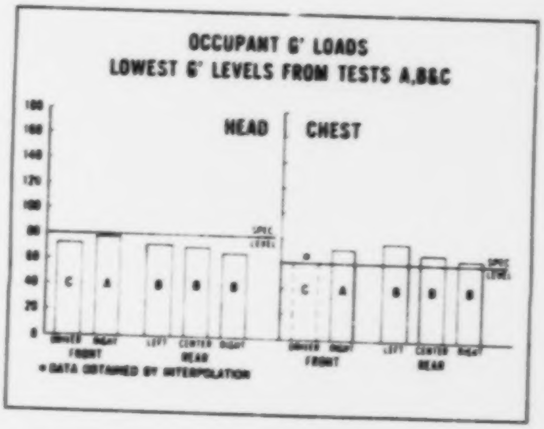


right front occupant stemmed from the right front air bag ripping. All rear occupants experienced loads that met the head objective and were only slightly high on the chest.





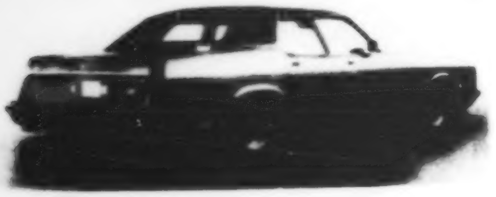
In the last barrier crash, Test C, only one load appeared to be a problem. Due to a failure in the pyrotechnic portion of the right front air bag inflator, the bag failed to fill properly and the right front occupant head load was very high. The newly developed driver system met the head and chest load objectives. Again, the rear occupants met the head objectives and were slightly high on the chest.



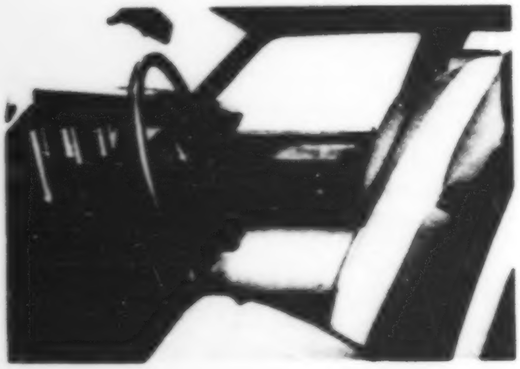
This slide depicts the lowest occupant g levels recorded for a given position in any of the three tests that you have just observed. We are encouraged that with the latest driver restraint system, plus properly functioning air bag systems for the other occupants, we should be able to achieve the objective of 80 g limit for the head. At the same time, we are only slightly over the 60 g chest limit. Please bear in mind that we have not yet been able to record these low levels for all occupants within the same crash test. Overcoming malfunctions in the air bags themselves will be a key step to accomplishing this.

INTERIOR AND EXTERIOR DESIGN

As I mentioned in the introduction, the design of the interior of the ESV is complete. We have maintained a strong surface resemblance to the Ford family of cars. However, it features a longer front-end to permit sufficient crush distance for a 50 mph impact. A rub strip is placed all around the car. The center grille is fixed to the bumper and moves with it to prevent damage in collisions up to 10 mph impact speed. The headlights are fixed and recessed to clear the bumper and yet meet the federal requirements for angular lighting.



The rear view reveals the relatively short trunk which was necessary in order to remain close to overall length objectives. In order to comply with the requirements of the contract, the separation of brake, turn and running lamp functions was required by DOT. As in the front, flexible panels are designed to limit body damage.



The interior features include fixed front seats for the driver and front right passenger which are separated by a control console, an important structural element of the car. The driver seat cushion height is adjustable, and the foot controls are movable to accommodate a wide range of driver sizes. The transmission shift lever and certain other controls are located in the console to provide space in the instrument panel area for restraint devices and associated hardware.

FORD ESV PROGRAM

CONCLUSION

CONCLUSION

In conclusion, I would like to comment on several important aspects of the program as we see it:

In some crashes, the manikins have met some of the government specifications for g loadings. We have had some setbacks and we have not solved all of the problems. Indeed, we have uncovered some new ones.

Generally, the car is approaching specification levels. However, these specifications describing the "survivability limits," and their correlation to human responses during impact, still require much intensive research before an honest prediction can be made about the significance of such instrument readings in "real world" highway accidents. Further, the serious problem of poor repeatability of test results with manikins remains to be resolved, if the readings from tests are to be considered meaningful.

It is appropriate to note that we started with an objective of developing an ESV which could be manufactured with present production techniques. We have not achieved this goal. Although the outside appearance of the Ford ESV is quite conventional, entirely new design approaches were necessary in many systems to achieve the performance levels outlined earlier. The incorporation of these new system designs in our ESV's was done on a high cost, experimental fabrication basis. In many instances, the system deviated considerably from design approaches compatible with proven mass production techniques at reasonable costs. As a Ford Motor Company executive pointed out in a speech recently, "It's important to remember that the 'E' in ESV stands for Experimental." We believe we have gone a long way toward achieving the E. It remains to be seen whether the "E" can be changed to "P" for production.

Nonetheless, we have learned a great deal from this program and believe that the Ford ESV design concept does provide a promising basis for future research and development.

Thank you.

UNITED STATES ESV PROGRAM STATUS

MR. ALBERT J. SLECHTER, *Acting Assistant Director*
Office of ESV Programs

Good afternoon ladies and gentlemen. I am pleased to report to you on the progress of the United States Experimental Safety Vehicle Program. This includes test results to date, some preliminary conclusions from our work, and an outline of our future plans leading to completion of the major ESV program objectives. To reaffirm the objectives originally set forth in our first conference in Paris, let me paraphrase them once again. We set out to, and are continuing to cooperate with the automobile industry world-wide through their governments to determine the feasible upper limits of total systems safety performance in passenger vehicles of all sizes.

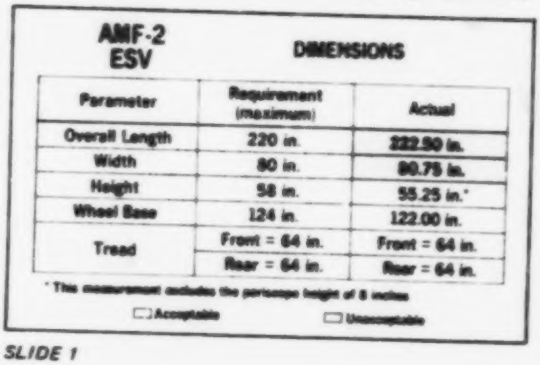
As the limits of feasibility are established, and as both the costs and benefits are determined, we hope to stimulate public awareness of the true net benefits to be gained by upgrading the overall level of automotive safety performance. Finally, we seek to develop a data base to support recommendations for practical systems safety performance standards which could be applicable to production vehicles of the latter part of this decade. The word practical is important, as many of the comments of the past few days question the practicability of some of the initial U.S. ESV specifications. I will explore this issue later in my presentation.

First, to a brief review of our progress. You have just heard of the progress of the Ford Motor Company for a December prototype delivery, and the near completion of the General Motors development with delivery of four test vehicles in late June. As Mr. Edwards outlined on Tuesday, the department took delivery in January of the first prototypes developed by Fairchild Industries and AMF, Incorporated.

Our test contractor, Dynamic Science, has completed testing of specified accident avoidance performance of these two cars, and has conducted a 50 mph flat barrier crash test of one of each of the two car designs. We are in the final stages of a comparative evaluation of the Fairchild and AMF competition, and will announce a follow-on contract award late this month. It is important to highlight two major constraints of the program under which these vehicles were developed. First, because AMF and Fairchild were in competition, they were forced to make all design decisions without DOT guidance, recognizing that a wrong decision on design performance might cost them the follow-on contract reward. Therefore, design tradeoffs that might compromise performance, but lead to a more practical approach, were discarded in some cases in order to improve their chance of winning the competition. The short 18 month schedule dictated a number of compromises, and particularly shortened available development test time prior to committing to final designs.

In spite of these constraints, the results of the program to date are very gratifying with the exception of final weight of the vehicles and restraint system performance.

Let's look now at the vehicles that were developed in this first prototype effort. This slide (Slide 1) shows that AMF marginally exceeded overall length and width, but was within specification limits on other dimensions. As shown on the next slide (Slide 2) Fairchild car marginally exceeded four of the specified dimensions. More important, both cars greatly exceeded the maximum weight specification,



AMF-2
ESV

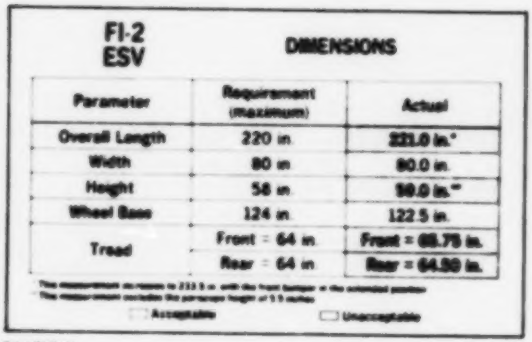
DIMENSIONS

Parameter	Requirement (maximum)	Actual
Overall Length	220 in.	222.90 in.
Width	80 in.	80.75 in.
Height	58 in.	55.25 in.*
Wheel Base	124 in.	122.00 in.
Tread	Front = 64 in.	Front = 64 in.
	Rear = 64 in.	Rear = 64 in.

* This measurement excludes the periscope height of 8 inches

☐ Acceptable ☐ Unacceptable

SLIDE 1



FI-2 ESV **DIMENSIONS**

Parameter	Requirement (maximum)	Actual
Overall Length	220 in.	221.0 in.*
Width	80 in.	80.0 in.
Height	58 in.	60.0 in.**
Wheel Base	124 in.	122.5 in.
Tread	Front = 64 in.	Front = 65.75 in.
	Rear = 64 in.	Rear = 64.50 in.

* [illegible]

** [illegible]

☐ Acceptable ☐ Unacceptable

SLIDE 2

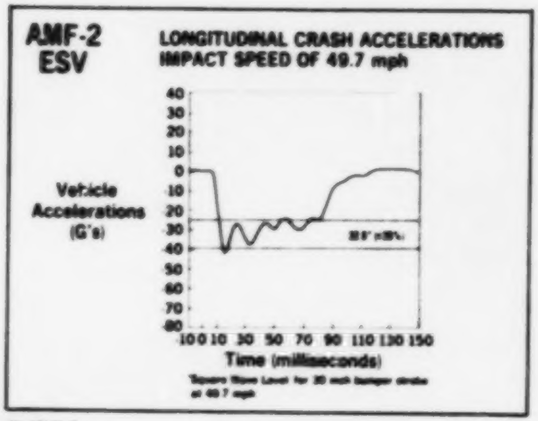
partly because of the reluctance of both contractors to decrease performance, but also because of some inherent specification problems. This high weight condition cannot be tolerated. Decreasing weight to a practical maximum will be a primary thrust of the next phase of our program.

I will now discuss the results of our testing, first the outcome of the crash test program. Crash testing consisted of low speed, 10 mph impacts in front and rear to verify the "no damage" capability of both designs. There were no occupants in the low speed crashes. Both cars performed without resulting damage and with decelerations at or below the specified maximum of 6 g's (low speed crash film).

For the high speed crash test, a comprehensive instrumentation system was constructed to obtain maximum information from these first crashes. Three 50th percentile dummies were placed in the driver, right front, and right rear seating positions. The vehicle was propelled on a 1200 foot track by a continuous cable system driven by two V-8 engines.

To check all this equipment and assure that the test procedures and facility were adequate, a 50 mph crash test was first conducted of a standard sized 1971 four-door car. This test also gave a visual indication of performance of any typical production vehicle undergoing the severe forces of a high speed crash. Let me emphasize that we were not interested in measuring performance of this car in a 50 mph crash, but were concerned primarily with facilities checkout. For this test, one unrestrained 50th percentile male anthropomorphic dummy was placed in the driver's position (production vehicle crash film).

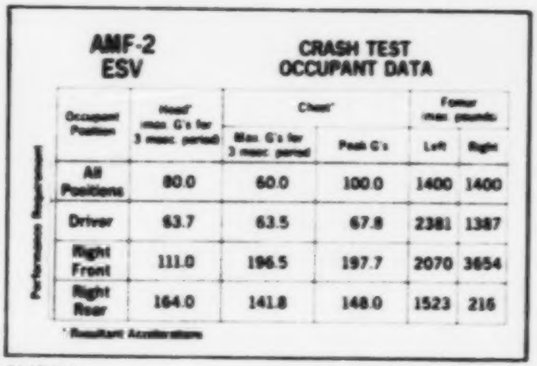
Now I would like to show you a film of the high speed crash of the AMF vehicle. For this design, as for Fairchild, this test was the first crash test at 50 mph (AMF vehicle crash film). This all important front energy management system performed as shown on the next slide (slide 3). The maximum vehicle decelerations for a period greater than 5 milliseconds were below the specification level of 40 g's, and averaged 29.7 g's over the major crash interval. The shape of the deceleration pulse closely follows the desired square wave response. It is shown here referenced against the theoretical deceleration required for 100% efficiency with a 30 inch stroke. A tolerance band of ±25%, which approximates the specification requirements is also shown. For a 50 mph crash, this is as good a square wave pulse shape as we have seen in any complete vehicle crash.



SLIDE 3

Subsequent to the AMF crash, all doors opened and closed normally, and all wheels rolled freely. Additionally, there was no passenger compartment intrusion.

The test dummy results are shown on the next slide (slide 4). Decelerations of the driver were within specification in the critical head and chest areas, with one marginal exception. The left femur of the driver exceeded the specification while the right femur was within specification.



AMF-2 ESV **CRASH TEST OCCUPANT DATA**

Occupant Position	Head* (max. G's for 3 msec. period)	Chest*		Femur (max. pounds)	
		Max. G's for 3 msec. period	Peak G's	Left	Right
All Positions	80.0	60.0	100.0	1400	1400
Driver	63.7	63.5	67.8	2381	1387
Right Front	111.0	196.5	197.7	2070	3654
Right Rear	164.0	141.8	148.0	1523	216

Performance Requirement

* Resultant Accelerations

SLIDE 4

The right front occupant decelerations exceeded the specification. The dummy kinematics appeared normal for air bag ridedown. Since no impacts with the vehicle interior were apparent, we conclude that the right front airbag was too hard and requires further development for the severe 50 mph crash condition.

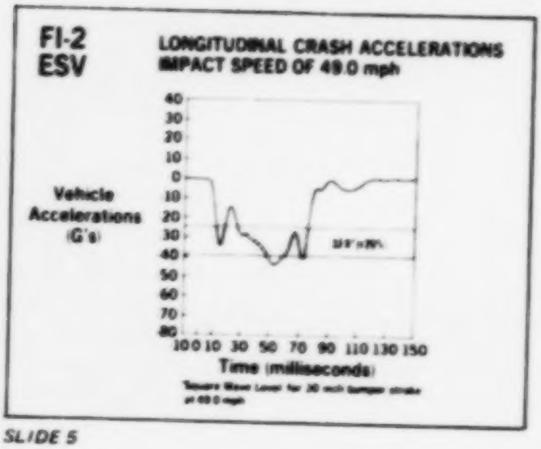
The right rear occupant exceeded the specification except for the right femur. Careful examination of films shows that the rear airbag inflated in an asymmetric fashion with the left side inflating more rapidly than the right. This caused the dummy to strike the airbag at a slight angle, and while ride-down appeared to be smooth, the dummy head struck the vehicle header during rebound. This caused high head decelerations exceeding specification requirements. In addition, a segment of glass from the backlight struck the rear dummy's head, further complicating the analysis of interior protection performance.

I will now discuss the performance of the Fairchild prototype in the same low speed and 50 mph crash conditions.

Low speed crash tests were conducted on April 14 and no damage resulted as you have seen on the previous film. The high speed test was conducted on April 18 with an impact speed of 49.0 mph. Many of you here today were present to witness this crash. I am sure you have read accounts of the crash, and the fact that the airbags did not function. The cause of this failure was traced to a human error which occurred during assembly at the Fairchild Industries facility. Two of the wires which provided an interface between the bumper hydraulic system pressure switches (which trigger the airbags) and the airbag electrical control unit were transposed. Because of the nature of the circuit design, reversal of these two wires could not be detected by the pre-test, automatic circuit monitoring system. This system indicated an "airbag ready" condition up to the moment before the crash. It was not possible to check the actuation of the bumper pressure switches which would have detected the problem. Such a test requires stroking the bumper system hydraulic pistons which was not practical. If a back-up inertial sensor had been provided, the airbags would have deployed, however, deployment probably would have been too late to have been of much value in a crash at this high velocity (FI vehicle crash film).

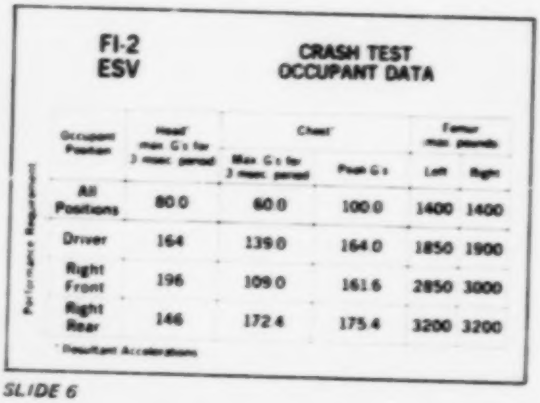
As I did in the case of the AMF vehicle, I will address vehicle performance first, and follow that with a discussion of dummy performance.

The maximum decelerations for a 5 millisecond period were about equal to the specification level of 40 g's. Here is an example of the associated vehicle deceleration pulse (slide 5). As you can see, this pulse deviates somewhat from the specified square wave response, but it is, nevertheless, an efficient pulse shape.



SLIDE 5

The dummy performance is shown on the next slide (slide 6). Recognizing that the airbag system did not function, the dummies were unrestrained except for interior padding and glazing. As could be anticipated, none of the dummy data was within the specification limits. While the right front and right rear dummy data for the AMF vehicle were, admittedly, beyond specification limits, the values were generally substantially lower than the corresponding dummy values for the Fairchild crash.



FI-2
ESV

CRASH TEST
OCCUPANT DATA

Occupant Position	Head* max. G's for 3 msec. period	Chest* Max. G's for 3 msec. period	Chest* Peak G's	Femur max. pounds Left	Femur max. pounds Right
All Positions (Performance Requirement)	80.0	60.0	100.0	1400	1400
Driver	164	139.0	164.0	1850	1900
Right Front	196	109.0	161.6	2850	3000
Right Rear	146	172.4	175.4	3200	3200

* Resultant Accelerations

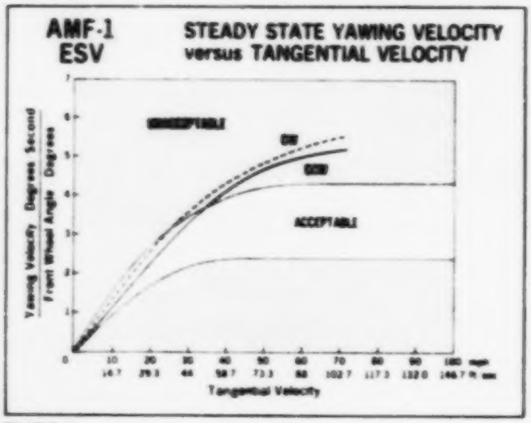
SLIDE 6

Although the data indicates that additional restraint system development is required, we are very encouraged by two major aspects of the structural performance. These are (1) the ability to prevent intrusion in the passenger compartment through controlled energy management of the front structures, and (2) elimination of vehicle pitching motion. The vehicles are too heavy, and they are obviously overdesigned, as a direct result of the design competition.

Let me turn now to the results of accident avoidance testing. The complete set of accident avoidance performance characteristics were also measured in tests at Dynamic Science. I will limit this discussion to the most significant areas of accident avoidance – steering, handling, and braking.

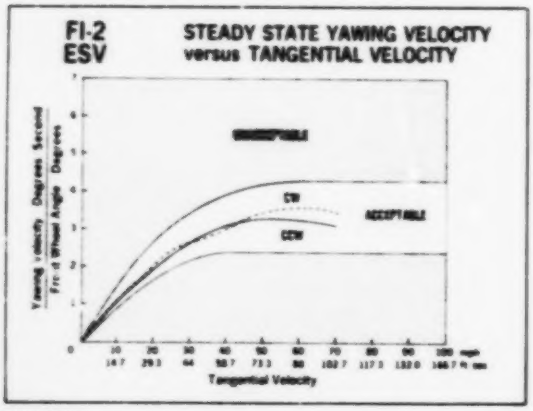
In the steering area we evaluated steady state yaw response, transient yaw response, and returnability.

This slide (slide 7) illustrates that the steady state yaw performance of the AMF vehicle was out of the specification envelope in both the clockwise and counterclockwise directions. These curves reflect a more neutral steer tendency. As has been indicated to us in previous meetings, some of you may prefer this performance.



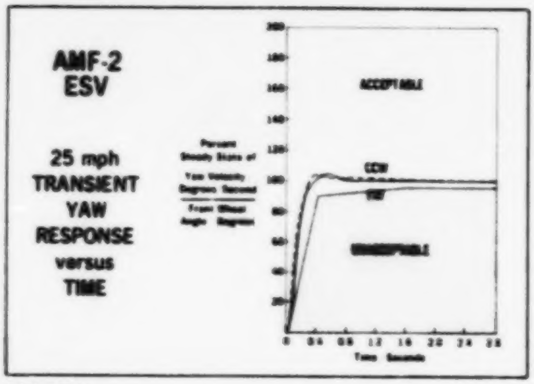
SLIDE 7

This slide (slide 8) shows that the Fairchild vehicle was within the specification envelope in both directions.

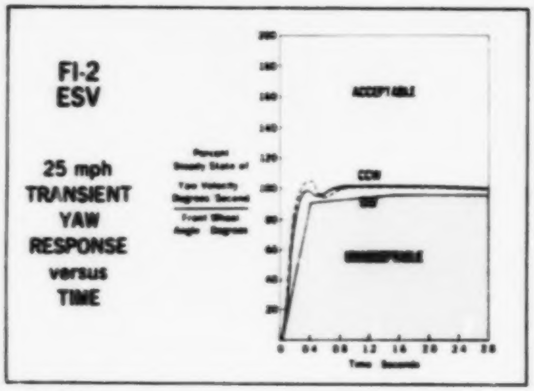


SLIDE 8

The AMF vehicle was within specification limits for transient yaw response at 25 and 70 mph (slide 7 and slide 8). The AMF 25 mph response is illustrated in the next slide (slide 9). The Fairchild vehicle was also within specification at 25 mph (slide 10), as well as 70 mph.

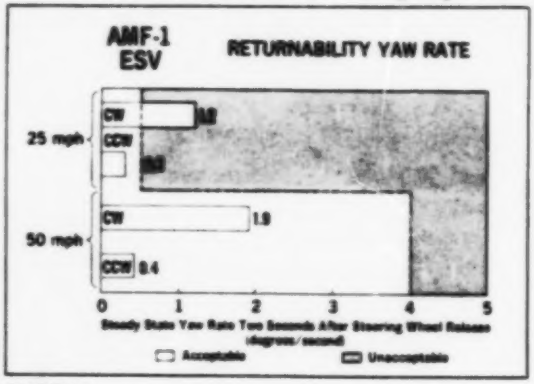


SLIDE 9



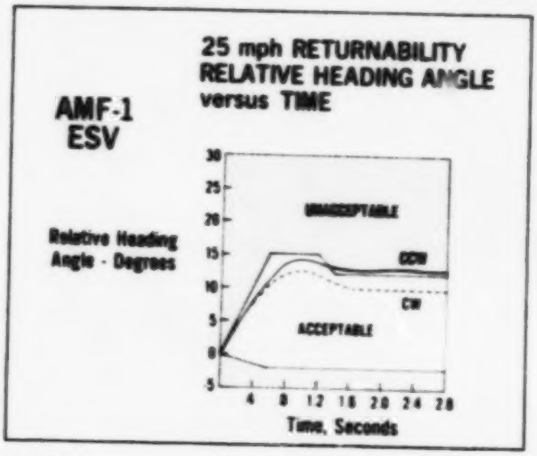
SLIDE 10

The returnability test consisted of driving the test vehicle at velocities of 25 mph and 50 mph around a fixed radius circular path to achieve a lateral acceleration of .4 g. After vehicle stability was attained, the steering wheel was released and measurements were taken of yaw rate and relative heading angle. The

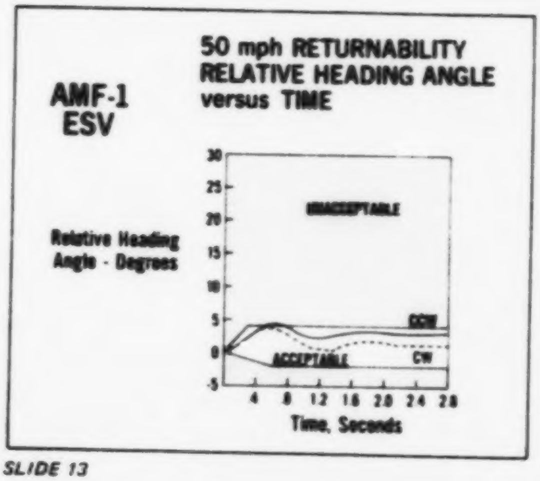


SLIDE 11

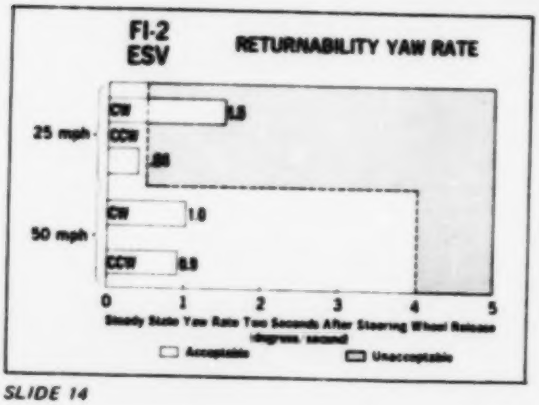
AMF vehicle yaw rates were within specification in all areas except 25 mph clockwise (slide 11). At 25 mph, the AMF relative heading angles for the clockwise direction were within the specification envelope but were slightly out of the envelope for the counterclockwise direction (slide 12). The AMF relative heading curves were within the envelope for 50 mph, although the counterclockwise curve is marginal at one point (slide 13). The Fairchild vehicle yaw rates were also within specification in all areas except 25 mph clockwise (slide 14). At 25 mph, the Fairchild relative heading angles for the clockwise direction were within the specification envelope, but were slightly out of the envelope for the counterclockwise direction (slide 15). The Fairchild relative heading curves were essentially within the envelope for 50 mph; however, the counterclockwise curve is marginal in two areas (slide 16).



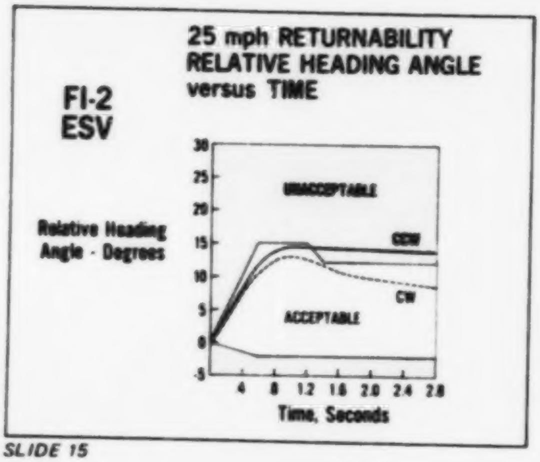
SLIDE 12



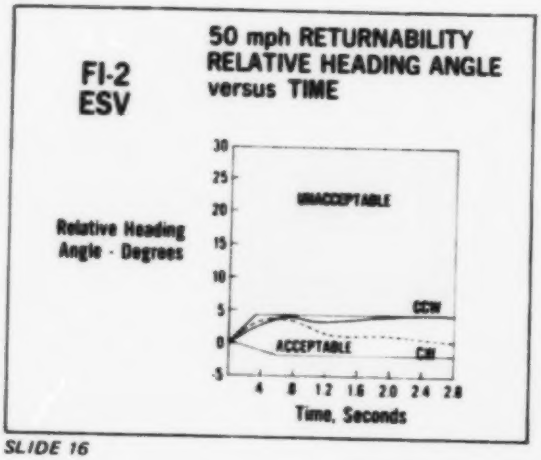
SLIDE 13



SLIDE 14

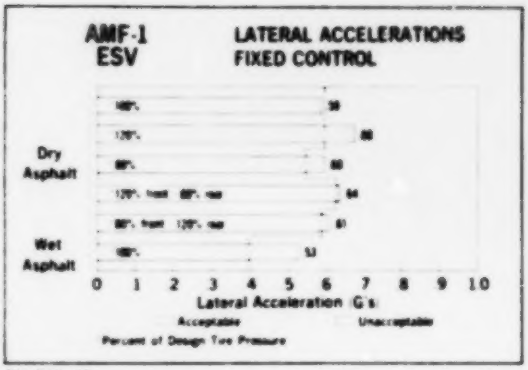


SLIDE 15



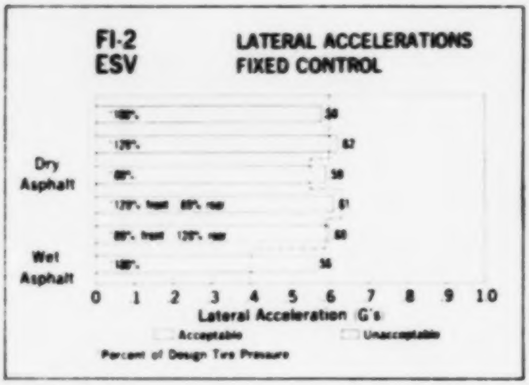
SLIDE 16

This slide (slide 17) reflects the AMF vehicle lateral accelerations for fixed control under various pavement and tire pressure conditions. Fixed control involves holding the steering wheel at a predetermined angle with no vernier adjustments. Similar data



SLIDE 17

are available for a manual control procedure. As you can see, this vehicle met or exceeded the minimum acceptable level for all but one of the test conditions. In similar tests (slide 18), the Fairchild vehicle exceeded the minimum acceptable levels with two exceptions.

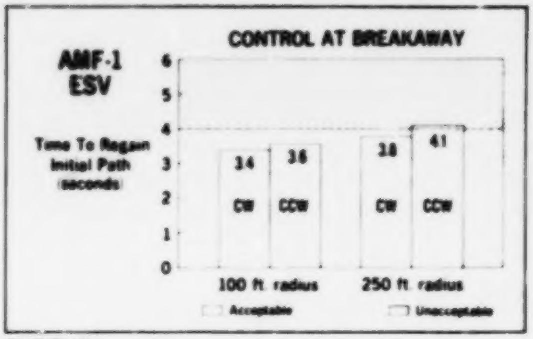


SLIDE 18

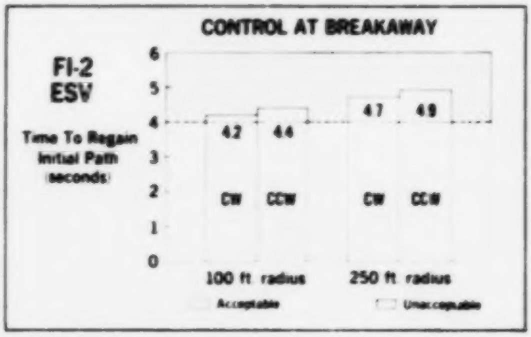
Control at breakaway is another important handling test. The AMF vehicle performed within the specification limits in three of the four test conditions (slide 19). The Fairchild vehicle slightly exceeded the specification limits for all four test conditions (slide 20).

In the areas of crosswind sensitivity and pavement irregularity sensitivity, both vehicles were well within specification limits. During the steering sensitivity tests, each of the vehicles exceeded the specification limits for one of eight test conditions.

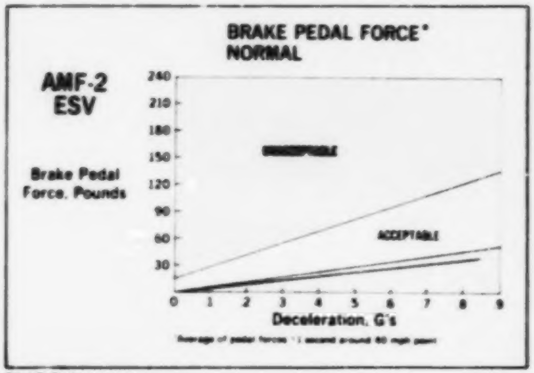
The third major accident avoidance area addressed braking performance. Brake pedal force was measured for three test conditions — normal, no booster, and rear brakes only. The AMF vehicle data were slightly below the performance envelope for the "normal" test condition (slide 21). For the "no booster" case, performance was within the envelope (slide 22).



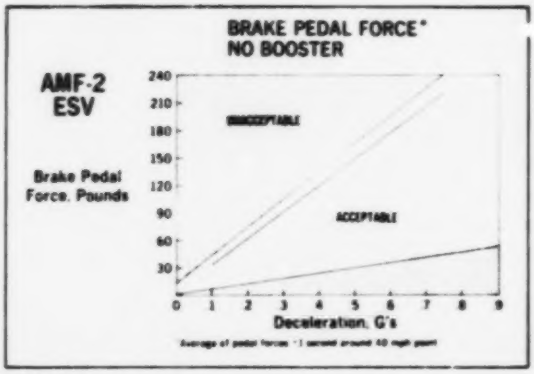
SLIDE 19



SLIDE 20

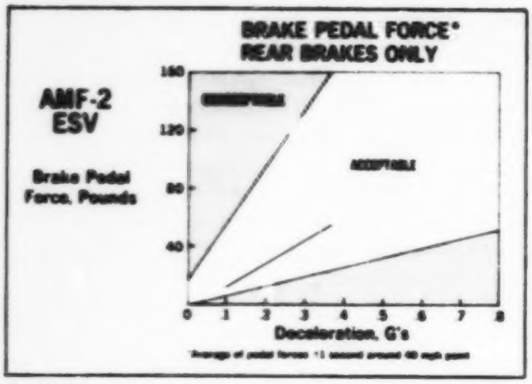


SLIDE 21



SLIDE 22

Performance was also within the envelope for the "rear brakes only" test condition (slide 23). This slide (slide 24) contains a summary of the significant brake performance parameters along with associated required performance levels and AMF vehicle performance levels. AMF brake system performance was generally quite good, with all performance within or near specified requirements.



SLIDE 23

AMF-2 ESV **BRAKE DATA SUMMARY**

Parameter	Requirement	Performance
Stopping Distance	155 ft. max.	158 ft.
Efficiency (wet surface)	80% min.	79.6%
Efficiency (40% load)	80% min.	73.3%
Emergency (front brakes out)	343 ft. max.	377 ft.
Emergency (no booster)	343 ft. max.	283 ft.
Parking Brake (uphill)	125 lbs. max.	122 lbs.
Parking Brake (downhill)	125 lbs. max.	132 lbs.

SLIDE 24

During the performance of brake tests on the Fairchild vehicle at the Dynamic Science test track, a number of brake system malfunctions occurred. We were not able to completely cure these malfunctions and, consequently, the braking performance of the vehicle was poor in a number of areas. Brake pedal forces for the "rear brakes only" test condition and parking brake data were within specification limits. Data from the remaining braking tests exceeded the specification limits, in some cases by a significant amount. Tests performed by Fairchild during their brake development program indicated the basic capability of the brake system to provide good performance. However, the independent test contractor could not verify this performance.

I can report in summary, that the combination of performance in both cars demonstrates that the accident avoidance performance requirements of our specification were achievable with some minor exceptions.

In accordance with our agreements to exchange information in this program, yesterday we made available to each participating country and company, a data package containing (1) microfilms of the complete Fairchild and AMF ESV design drawings and other significant data, and (2) movies of our baseline and prototype crashes. In July, you will be sent copies of the final reports of our contractors, including a report from Dynamic Science on the complete performance characteristics of both vehicles.

Having seen the results of our tests, let me summarize qualitatively some preliminary conclusions referenced to our original specifications.

Our overall goal in accident avoidance was to determine whether the accident avoidance characteristics to which American drivers are accustomed could be maintained or improved upon when significant changes are made in structure, configuration, and weight distribution to provide crashworthiness. We believe that we have demonstrated that accident avoidance at this level of performance can be achieved with such modifications.

Our preliminary conclusions in crashworthiness are more complex. We have been successful in demonstrating the technical feasibility of some of our goals while additional effort is still required for others.

Our status with regard to major crashworthiness goals falls into three major areas: (1) front end energy absorption, (2) passenger compartment integrity, and (3) passive occupant protection.

The area of front end energy absorption is of prime importance. It has been demonstrated that it is technically feasible to build energy absorbers which provide efficient performance in frontal impacts with fixed rigid barriers, yet automatically provide acceptable "soft-nosed" performance in car-to-car collisions. Therefore, a major conclusion is that effort can now shift with assurance to the development of lighter, more practical systems having these desirable characteristics.

There is ample evidence to support this conclusion and I would like to present some of this evidence for your consideration.

First, there is the fact that, although both the AMF and Fairchild cars were much heavier than desired, both vehicles provided low decelerations when impacted into fixed rigid barriers at low speed. In the 50 mph tests, near-optimum force responses were achieved. Deformations of approximately 30 inches and average decelerations below 40 g's were recorded. Development test results from both contractors showed the same type of excellent and efficient performance at intermediate velocities where self-regulated reaction forces proportional to the impact velocities were measured. It can be analytically deduced from the barrier test results that these systems would automatically provide soft, variable reaction forces (that is, low aggressiveness) in impacts with other automobiles over a range of vehicle weights and impact velocities.

Some controversy has existed concerning the feasibility of providing both good crashworthiness and low aggressiveness characteristics in a single system. Therefore, we recently conducted a special series of tests to demonstrate such performance empirically. The rear of a 1968 Plymouth sedan was impacted at 60 mph by a vehicle equipped with a fixed force front end design. The AMF vehicle which had previously been subjected to the high speed barrier crash, was refurbished and used as a striking vehicle in the same kind of test. Three significant results were observed during these tests. (1) The deformation of the struck vehicle was 52 inches when struck by the AMF system and 70 inches when struck by the fixed force system. (2) The energy absorbing stroke of the AMF vehicle was 15 inches whereas the fixed force striking vehicle stroked less than one inch. (3) A computer run which assumed a conventional vehicle was used as the striking car predicted a deformation of the struck vehicle of approximately 67 inches, a value between that predicted for the AMF and fixed force systems. Additionally, it was shown from the computer runs that, of the total energy absorbed by both vehicles in each test case, the fixed force front end absorbed essentially 0%, the production car absorbed about 5%, and the AMF vehicle absorbed about 20%.

It can be seen from these results that the AMF and Fairchild vehicles do not depend exclusively on tank-like properties for providing crash safety although they are admittedly heavy. In fact, comparing them with tanks in their interaction with other automobiles is quite inappropriate and would appear to result from lack of understanding of the front end design. Today's production vehicles have been analytically shown to be more aggressive in recent computer crash simulations.

Although we can report this low aggressiveness performance we have tentatively concluded that long stroke hydraulic systems in their present form are not practical for all automobile applications in spite of the excellent performance characteristics just described. A major positive feature of the systems for the family sedan program was that they could be designed, fabricated, tested and modified as required within our very tight schedule. A more realistic concept may be a "hybrid" system which combines a hydraulic or similar system in series with a fixed force system which comes into play at the higher impact volocities. Such a system will, of necessity, trade off some, but not all, of the low aggressiveness shown by the long stroking hydraulic system.

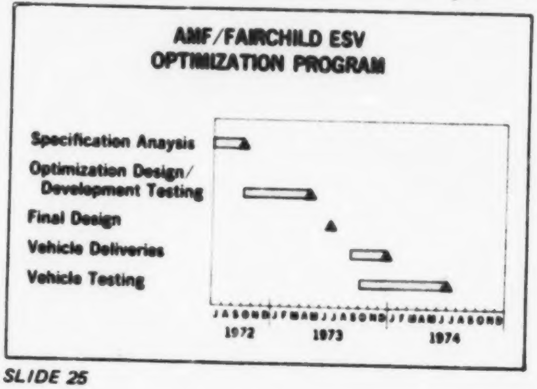
Several of the manufacturers who are here today have made contributions related to this concept. The Ford program is expected to provide much-needed data on the performance of a non-hydraulic stroking system which is partially velocity sensitive over a nine inch stroke followed by a controlled deformation of the frame and upper level structure. Volkswagen has previously reported an excellent theoretical study on crash energy management. The VW studies have not only dealt with hybrid systems but have related the velocity sensitive stroke requirements to the mass of the vehicle. Considering all available information, we believe that the hybrid systems should be explored further. They were, in fact, suggested by our original specification. We will do additional work on the concept in the next phase of our program.

The second major element of our program status is the maintenance of passenger compartment integrity and the prevention of harmful intrusion. Our preliminary conclusion here is that technical feasibility has been demonstrated but at the expense of weight. With some adjustments to the specification and a non-competitive follow on program, we expect to demonstrate good passenger compartment integrity at reasonable weight.

The third major element of our program status is passive occupant protection in 50 mph barrier crashes. Obviously, this very difficult goal has not been achieved to date. However, we are optimistic as a result of the activities that have been reported by other participants. We would cite the work of General Motors on inflatable restraints and several on-going efforts (particularly the VW performance described yesterday) on passive belts.

Now, I would like to discuss what we intend to do in the next two years. You may recall that our original plan put forth in Paris included the purchase of twelve additional ESV's from the contractor winning this competition. It is clear, however, that the total system specification that these first cars were designed to, must be modified in certain areas to increase the practicality of ensuing designs. To simply build 12 additional identical cars would ignore the significant amount of knowledge we have gained in the last two years. Therefore, we intend to engage in the following plan of action with either AMF or Fairchild Industries beginning on July 1.

Our overall optimization program schedule is summarized on this slide (slide 25). We plan to complete an analysis of the specification by the end of this summer. Design and development testing will be conducted in the fall of this year and the spring of next year. An optimized design should be complete by next summer and vehicles will be delivered during the fall and winter months of next year. Vehicle testing will commence next fall and continue into the summer of 1974.



SLIDE 25

The crashworthiness specifications will carefully consider the car-to-car crash mode in addition to the single vehicle crash. As I indicated earlier in the rear end crash example, design of the vehicle front structures for good barrier crash performance need not result in a very aggressive vehicle in car-to-car crashes. It also appears that the larger passenger car design must be tailored to take a greater responsibility in crashes between large and small cars. While we intend to continue work in optimizing barrier crash performance, I wish to emphasize that continuing importance will be given in the U.S. program toward lowering the aggressiveness of the larger vehicle.

For your information, the DOT will initiate a research project next month wherein various front structure concepts, including hydraulic and fixed force, will be tested under controlled conditions to measure aggressiveness characteristics. We expect that this project will evolve important information to support any future rule making recommendations we may make concerning vehicle aggressiveness.

Let me point out some of the directions in which we expect to move with the optimized specification. The front flat barrier crashworthiness will remain at or near 50 mph unless aggressiveness, cost/effectiveness, or practicality factors dictate a reduction. The pole impact requirement in front will probably be somewhat reduced. Rear impact crash performance will be reduced in the face of recognized cost/benefit factors. Car impacts in the side will remain at or near 30 mph, but some small reduction of the side pole impact requirement may be made. Rollover performance will be modified to a cart-type test in order to simplify test procedures. Intrusion requirements will be changed to allow more intrusion in non-safety related areas of the passenger compartment.

For occupant protection, we will examine the priority of each seating position relative to highway crash experience. If data dictates, we may elect to provide less crash protection in the rear seat positions for some crash modes as a cost effective trade-off and/or a more practical design. The requirement for passive restraints in the rear seating positions will be carefully re-evaluated based on cost effectiveness and practicality. In the related area of injury criteria, we will follow the general guidance of FMVSS 208, recognizing that this is the focal point for all continuing dialogue concerning human tolerance.

With regard to occupant sizes, it has been determined that designing interior protection for the full range of 5th to 95th percentile dummies can cause a severe weight penalty or serious design complications. Therefore, the size requirements for occupants will be reexamined with the goal of providing interior dimensions based on those of existing cars available to the consumer and the most cost effective protection.

Accident avoidance specifications will be modified to the extent that new information dictates. We still intend to provide for our vehicle, handling quality equal to or better than full size American sedans.

In order that this so-called optimized specification includes the best inputs from all knowledgeable and concerned participants, we wish to invite your comments during the summer months. My office will, in July, send to each participating country and company, a copy of a proposed optimized specification. We request that you review and comment by early September in order to meet our goal of a final specification by the end of September. I certainly hope that your inputs will be based on cost/benefit, design practicality, or other quantitative supporting data rather than qualitative opinions.

We may request to visit some of you individually during the summer if that appears necessary. I am sure you recognize the importance of this final specification draft since it will begin to characterize the performance of the state-of-the-art safety car of this decade. This concludes my presentation. Thank you for your attention.

DISCUSSION OF THE TECHNICAL PRESENTATIONS

SECTION 2 PART 8

QUESTIONS AND ANSWERS REGARDING THE TECHNICAL PRESENTATIONS

MR. JOHN A. EDWARDS, *Chairman*

Associate Administrator for Research and Development, Research Institute, National Highway Traffic Safety Administration, United States Department of Transportation

Question: Mr. Chairman, perhaps I could start the ball rolling for you. I would like to direct one question to the French delegation and to make one point to the German delegation, if I may.

I would be very much interested to know the reason in the French aggressivity test for the plate which appeared on the front of one vehicle in the frontal collisions. There was a plate attached to the front of one particular vehicle.

Mr. Chairman, I have been asked to identify myself, too, as well. My name is Waller, from Vauxhall Motors.

The second point which I would like to direct to the German delegation in respect to their running lights. They proposed, I think it was Volkswagen, green running lights. I do understand that approximately 10 or 12 percent of the male population suffer from green color blindness and I think this could be an operational problem of confusing running lights with other signaling lamps, and I think this point would need to be watched in the evaluation of any particular system.

Thank you, Mr. Chairman.

Answer: My name is Ventre. I am from the Renault Company. I have described it rather vaguely in my report and probably much too hastily. The plate that was installed between the two cars had two essential purposes. The first one was to constitute a flat interface that was absolutely rigorously flat between the two cars at the moment of impact, since the mathematical model that was the basis of our computation was based on the hypothesis that that interface would remain flat during the entire duration of the impact.

Secondly, this plate also allowed us to follow the movement of the interface at impact between the two cars on the film during the entire impact duration because the mathematical model did not allow us to know exactly how the various rigidity points would be distributed during this impact. I had no time to report and to comment on the movement of this plate, but it is not irregular movement.

Answer: Professor Fiala, Volkswagen. The problems involved are connected with daylight. Our investigation on a car following simulator are under way and we are looking forward to this research.

Mr. Edwards: I might add a little to that. We have conducted some investigations on various coded systems and colored systems for tail lighting within the NHTSA and have a report that we are rather proud of, and it has had a direct influence actually on our rulemaking in this area. We believe that positions of lights should be carefully delineated but that the use of various color codes is something that has to be taken and handled very carefully.

Question: Mr. Chairman, Jack Thompson, United States. I would like to direct a question to the VW delegation on the use of the knee restraint belt and whether it has been evaluated with different size occupants.

Answer: Professor Fiala, Volkswagen. The connecting points of the knee belt, where the knee belts are fixed to the car, gives an angle which depends on the length of the femur. This angle is small, if the femur is short, as with a five percentile female. This angle is big, if there is a 95 percentile man. This angle

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of the forces then gives the size of the force for the femur load, and so we achieve different femur loads, depending on the length of the femur. Thus, the femur load varies according to the size and to the weight of the passenger.

Question: My name is Rupp, AMF, United States delegation. I would like to address my question to the German delegation. Dr. Fiala showed some cost-benefit slides for the various subsystems in the Volkswagen. I would like to know what criteria or factors were considered in benefits, what constitutes a benefit? How is that defined?

Answer: Dr. Appel, Volkswagen. As benefit, we regarded the monetary benefit and we calculated or considered for prevented death the amount of \$43,000, and for injury prevented \$2,200. These are the benefits, prevented death and injuries.

Question: Mr. Edwards. I gather therefore that suicidal impact is a factor in this. Mr. Rupp. Does that satisfy your question?

Answer: Yes.

Question: Conrad Cook, Department of Transportation. I would like to address a question to the United Kingdom concerning the active ride control system, and I guess I am concerned about the performance of the pendulus mass and how it responds to the overall heave of the vehicle and actually what it does in the event of a collision where we do get into vertical accelerations at the time of the collisions?

Answer: Bainbridge, United Kingdom. The pendulus mass normally operates as a spring mass damper system which absolutely takes the same characteristic as the suspension of the car itself. In any collision condition, of course, the accelerations will be taken up by the pendulus mass and will be reflected as a movement of the suspension and the car itself.

Question: My name is Slechter, Department of Transportation. I would like to ask the German delegation, perhaps Professor Fiala or one of the Volkswagen people or one of the German government people who talked about statistics related to accidents on the road. I would like to ask if, as a result of the analysis that you have done, whether or not you are yet in a position to make a positive recommendation of a change to the front-end specification of the car relative to crashworthiness versus aggressiveness?

What I am looking for here is if we are talking about trading off to a degree the high-speed crashworthiness for less aggressiveness, and you seem to indicate that the car to car collision is of course a very important collision factor, does the data that you now have, does the analysis that you have accomplished lead you to a conclusion at this time, or would you propose that you will have a conclusion in the near future that would allow a recommendation that would modify the existing specifications?

Answer: Professor Fiala, Volkswagen. We presented our investigation to the NHTSA I think last year or so, and this is based on an assumption that the car ranges between 2,000 and 4,000 pounds and the mean consideration is 30 g. If we will accept this value in the future I think we could proceed with this suggestion, but this suggestion is not limited to certain mean decelerations or certain car weights, so it is up to now a suggestion. I think we should work on that and come up with a solution which everybody can accept.

Question: Mr. Slechter. So that you are not proposing at this point in time a particular fixed barrier equivalent crash speed, rather work the problem of relative "G" loadings on the two cars?

Answer: Yes.

SECTION 3

DISCUSSION: RULEMAKING AND THE EXPERIMENTAL SAFETY VEHICLE PROGRAM

Panel Members

Mr. Douglas W. Toms, *Administrator, National Highway Traffic Safety Administration, United States Department of Transportation*
Mr. John A. Edwards, *Associate Administrator for Research and Development, Research Institute, National Highway Traffic Safety Administration, United States Department of Transportation*
Mr. Robert L. Carter, *Associate Administrator for Motor Vehicle Programs, National Highway Traffic Safety Administration, United States Department of Transportation*
Mr. Albert J. Slechter, *Assistant Director, Office of Experimental Safety Vehicle Programs, National Highway Traffic Safety Administration, United States Department of Transportation*
Mr. Elwood T. Driver, *Director, Office of Operating Systems, Motor Vehicle Programs, National Highway Traffic Safety Administration, United States Department of Transportation*
Mr. James E. Hofferberth, *Chief, Structures Division, Office of Crashworthiness Programs, Motor Vehicle Programs, National Highway Traffic Safety Administration, United States Department of Transportation*

Mr. Ralph T. Millet, *President of the Automobile Importers of America*
Dr. Gunther Brenken, *Executive Director, National Association of Auto Industries, Federal Republic of Germany*
Mr. Peter N. Gerosa, *Head of the Road Safety (Vehicle Standards) Division of the United Kingdom Department of the Environment*

RULE-MAKING AND THE EXPERIMENTAL SAFETY VEHICLE PROGRAM

SECTION 3 PART 1

STATEMENT

MR. RALPH T. MILLET, *President*

Automotive Importers of America

I would like to preface my remarks today with some words of wisdom spoken by Secretary Volpe at the initiation of this conference last Tuesday. He said that a major objective of the ESV program was, and I quote, "to incorporate the safety features demonstrated by the prototype ESV's into requirements for mass production vehicles. I am sure you will all be interested in the session that has been scheduled at this conference to discuss the relationship of the ESV program to the safety standards we are working on for the near future . All of the governments represented here today must begin to study the ways and means by which the work done on ESV's can be translated into production model requirements. We in the Department of Transportation are working on this now, and are prepared to exchange our ideas as to how this can best be accomplished with all of our ESV partners. At the appropriate time, I hope another international meeting can be held on this all-important topic to discuss how we can assure the maximum uniformity, on the international level, of vehicle safety standards."

AIA applauds this recognition by Secretary Volpe that as the ESV development programs proceed, it is becoming more and more obvious that the ESV results are leading to conflicts with the rulemaking actions that have been proposed in the Program Plan for Motor Vehicle Safety Standards. Since the final ESV specifications will be promulgated at the end of the year, the deadline for reconciliation is rapidly approaching.

The manufacturers' dilemma is this. We are expending as Secretary Volpe stated in his opening remarks "tens of thousands of scarce engineering man-hours on the ESV project," the announced purpose of which is to establish new and different regulations. The vague rulemaking proposal in the Program Plan Book also demands these scarce and limited engineering man-hours. In addition, and at the same time, these resources are severely burdened by the requirements of current mushrooming DOT Regulations.

Even worse, rulemaking actions currently proposed and those contained in the Program Plan Book are not awaiting the results of the tremendous research effort being expended in the ESV Program but are proceeding rapidly along a divergent course.

Some of the specific conflicting areas are the requirements regarding injury criteria, energy management, visibility, exterior protection, and accident avoidance.

If this conflict continues, the public will suffer because the design of new, safer vehicles is unquestionably being delayed by uncertainty, diversion, and dilution of the design direction. Should we follow the uncertain Program Plans or should we target assumed results of the ESV Program?

The urgent need for synchronization is wisely signaled by Secretary Volpe's call for an International Conference to resolve the differences between the ESV specifications and rulemaking actions.

In the meantime it is perfectly clear that there should be a moratorium at least on program plan proposals in conflict with ESV findings.

In short, we applaud Secretary Volpe's recognition of these problems confronting manufacturers. We trust that his Department can lead us to a quick resolution of the collision course between the ESV program and the Program Plan Book. Without such a resolution, delay in the building of safer cars for the public will be inevitable.

RESPONSE

Mr. Toms, NHTSA: I am Doug Toms, and I would like to attempt a response to Ralph Millet and his presentation.

First, I would like to point out to all of us here, in particular for those of you who may not be aware

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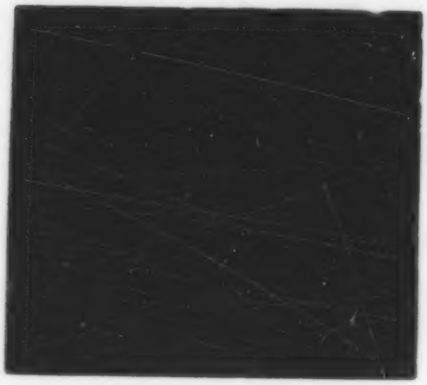
that Ralph does chair a very critical subcommittee on the National Motor Vehicle Safety Advisory Council, and Ralph's position as President of the AIA places him in a spot where he is particularly well informed and well advised. And I might compliment Ralph on the outstanding manner in which he carries out his duties.

I guess the first thing that I would like to say in response to Ralph's request is that I don't know how quickly we can solve these problems. Secondly, I agree with all those who have expressed the need for an international conference. Obviously, we would not have encouraged Secretary Volpe to say that if we did not believe in it. Further, we would not encourage such an international conference if we had all the answers. Clearly, we do not have all the answers. Clearly, much of the technical information that has been presented here at this conference this week is such that it challenges us to keep up with it, to properly assimilate it, and determine ways in which it can be translated into rules.

Ralph, I think that you are truly on-the-money when you lament the large number of engineering man-hours that have gone into ESV programs around the world and, indeed, it would be a shame if they did not get translated into useful programs that would benefit all mankind. So, we recognize that need.

I think the toughest question that Mr. Millet posed to us deals with the conflicts in our Program Plan and the specifications for our ESV. The most honest statement that I can make to all of you is that this is most difficult for us internally in the Department of Transportation. There are many disagreements among our scientists and our engineers as to how we can continue to assist you in your new model development, in your own corporate planning through the issuance of a program plan and how we can adapt this Program Plan to follow the guidance that is becoming evident from the Experimental Safety Vehicle Program.

Ladies and gentlemen, if I had a clear answer that I could give to you, rest assured I would state it. The best thing I can say is that it is very difficult; we recognize the problem, we solicit your suggestions and we will make a sincere effort to remain as open-minded on these issues as we possibly can.



RULE-MAKING AND THE EXPERIMENTAL SAFETY VEHICLE PROGRAM

SECTION 3 PART 2

STATEMENTS AND QUESTIONS POSED

DR. GUNTHER W. BRENKEN, *Executive Director*

National Association of Auto Industries
Federal Republic of Germany

Experimental safety vehicles serve the purpose of establishing procedures to increase active and passive safety. After completion of all testing and an international exchange of information, a further improved cost/benefit analysis must be established and only then may a basic avenue for future standard setting be gained. The state-of-the-art of the ESV development already allows for recognition that only increasingly smaller benefits can be gained in contrast to sharply rising expenditures. It must also be considered that intended measures for environmental protection will have an additional negative effect on costs, and in reference to these costs we must consider the consumer.

At the insistence of the U.S. Government the ESV program has been raised to an international project. In contrast, it should be noted that present legislation in the U.S. was promulgated on an exclusively unilateral basis. The responsible committee in Europe for international motor vehicle legislation is the Working Party 29 of the Economic Commission of Europe (ECE) in Geneva.

Happily it has been noted that the U.S. representatives have lately become more active in the WP 29 and have been involved decisively in the completion of a number of regulations. This development is welcomed by the automobile manufacturers of the ECE member countries.

NHTSA has established a program for the continued development of technical regulations, and the requirements contained therein have often been changed or made more stringent, with the leadtimes being shortened or lengthened. This has created great uncertainty among the automobile manufacturers. By this procedure, additional costs, including the cost of ESV development providing they were based on production vehicles which amount up to several hundred million dollars, have been created. An especially sharp increase in the additional costs for production type vehicles will be noted when the leadtime of effective dates of future rule making will be shortened. With more stringent technical requirements longer leadtimes of five to seven years are realistic. This statement can be true only for new vehicle models, since modifications on production models or on vehicles already in operation, generally is out of the question.

It must be determined that the ESV Program stresses the technical aspect of the vehicle too much and neglects the other factors in traffic situations, such as the driver and the road. In addition, an internationally acknowledged anthropomorphic test device for determination of injury criteria is still missing. The cost/benefit analysis of safety measures can lead to results for evaluation only, when each of the three factors vehicle, driver and road are fully considered.

We therefore present the following six questions to NHTSA

1. Does NHTSA think that consideration for setting new legal requirements can be given only after completion of all ESV tests in 1974, and after the intended exchange of information, and a thorough cost/benefit analysis?

2. Does NHTSA intend to also conduct biomechanical investigations for a uniform determination of injury criteria and test devices?
3. Is NHTSA willing to make available to the competent agencies the knowledge gained from the ESV program for the protection of all people of all nations, as a basis for international, or at least consistent legislation in all countries, and to refrain from exclusively individual efforts in rule-making?
4. May the technical requirements and the effective dates contained in the new NHTSA Program Plan be considered final and binding over a longer time period (until 1980)?
5. Does NHTSA acknowledge that most of the more stringent technical requirements can be achieved only after appropriate long leadtimes and only for new vehicle models?
6. What are NHTSA's intentions in regard to incorporation of the two other factors of highway traffic — the driver and the road — into the evaluation of the ESV results and into the considerations concerning future rule-making?

Answer — Mr. Toms, NHTSA. I will attempt to answer each of your six questions as concisely and as directly as I can. I hope that you will recognize that I may not be able, due to the breadth of some of the questions, to give you complete and thorough answers, but for the sake of time I will do my best.

I would further like to compliment you on very thoughtful questions and obviously very important questions to us all.

I will go through and give you a short answer and then I will go back and elaborate briefly.

My answer to number one would be, yes, in part. In other words, yes in some parts and perhaps no on others. We are aware of the importance of completing the testing and we are taking into consideration cost benefit.

On number two, yes.

On number three, yes, in part.

On number four, that one is both yes and no. Principally, I say yes and no because the Program Plan changes regularly, in other words we try hard to keep abreast of developments.

On number five, yes, but five to seven year lead time would not be accommodated by us under all conditions.

My answer on six is basically yes.

Now I will go back through and try to elaborate a little bit and give my colleagues a chance to add their comments.

Starting with number one, there have been a great many questions about cost — benefit ratios. We had developed cost-benefit studies on most of our major rulemaking actions. I am constantly asked why we do not publicly present these cost-benefit ratios. There has been a considerable technical and scientific argument in the United States about the assumptions that center around cost-benefit relationships. Such things as how much is a life worth. We find very little agreement on what that figure should be. There is considerable disagreement as to the average income of a man during his lifetime in how many of the indirect costs should be considered in such a calculation. We were hopeful that some of these could be resolved before we attempted to make our cost-benefit ratios public. We are not ashamed of them, but we do recognize that a great many people do not agree with them due to these differences on the assumptions.

In regard to completing our testing before we rulemake, I rather view the situation that we rulemake all the time and we test all the time and the two processes must complement one another. I would pause for my colleagues to add comments if they would like.

Mr. Carter, NHTSA. I might just comment on the benefit cost studies. One of our big problems there is in obtaining accurate cost data from the industry. So we exercise our best judgment and we would like to enlist your support in coming up with actual costs.

Mr. Toms. Yes, you fellows are really not very helpful on that subject.

On number two, yes, we do have a great deal of biomechanical research underway because this is directly in John Edwards' program and I think John would like to comment in detail.

Mr. Edwards. We have currently approximately six projects underway within our own organization; that is in our in-house Safety Systems Laboratories. We have a two year program to develop improved performance requirements for dummies. The current effort is directed toward improvement of the head-neck combination. The work in terms of human tolerance levels in the biomechanics area is being pushed. It is being funded at increasingly higher levels each year and has been a program that is not in need of initiation because it has been underway for some three years, at least four years to date, and the level of effort in this area is going up. Our level of effort for the present year is at about a million dollars. So, I feel that we are actively pursuing the research activity in that area.

Mr. Toms. I think that a word needs to be stated, John, about human testing.

Mr Edwards We wish to expand this much further and we have presently been conducting human tests. We are open to any suggestions from the automobile industry worldwide as to how that human testing may be expanded. We would be willing to utilize our military resources for human volunteers to expand that testing in different sites and perhaps under different conditions. I rank as a very high priority a program that would crash regular automobiles with various restraint systems into the barrier and into other cars with human volunteers inside. I think it is very important that we get to such a program as quickly as we possibly can; and within the limits of how you protect people, in other words, you do not wish to hurt people in this testing, how to protect them, how to deal with the liability, and how to instrument humans in these tests, any answers or any suggestions that people would wish to pose would assist us in moving more quickly in this direction. I think that all of you appreciate how enormously difficult human testing is and how precarious that type of testing is. But even in light of the difficulty of it, we count it as very important and one of the necessary steps to establish what the human tolerance levels are in crashes.

Mr Toms If there be no challenges to that response, I will proceed with number three.

I think that international rulemaking is enormously desirable and I have said repeatedly in my public statements worldwide that I would do everything in my personal power to cooperate and participate in any kind of international rulemaking. I have had a number of talks with Mr. Pocci on the subject; talked about it this week. Further, I would pledge that any and all ESV data available to us in the government would be made available to any international rulemaking body that were properly recognized.

I added the word "in-part" to my first answer because I realize that there are different needs in different nations, both in terms of geographical terrain, climate, economy, and a host of other variables. Therefore, many countries may not, due to the prosperity of their economy, or their geography, wish to participate in international rulemaking, but within those limits we would be pleased to do everything we can to engage in international rulemaking. I am on record as saying that at any time we adopt a rule and a recognized international body adopts a rule that runs counter to it, and the information is persuasive that we should change, that I will immediately enter into negotiations to try to accommodate those changes.

Now, I say the information is persuasive. I can recognize that sometimes international bodies would rulemake in such a manner that would not be in the public interest of the American motorist. That is possible and with that caveat I would certainly enter into any kind of international rulemaking. Would my colleagues wish to respond further to item three?

John reminds me that a part of your question did deal with national rulemaking and I think the answer to that, John, was in part dealt with in my statement that we would go back and revise, that we would not withhold rulemaking while waiting for international activity. It is my openly expressed feeling that international rulemaking, because of the variable needs of the nations, is very slow and cumbersome. We would not want to withhold safety from our people while waiting for international rulemaking. We will go back and make amendments or modifications to be in conformity with international rules.

Are there any challenges to our answers on item three or a need for further clarification?

On item four, is our Program Plan obligatory? Well, that is a tough one. Yes and no. Certainly, if you want to sell your cars in our country, you have to meet our national standards. By the same token, we recognize that we are not always right, in that we can make mistakes. We recognize that very often, cars may be designed and components developed that would be superior to the rules that we have set for our country. I would urge you that any time you feel that there might be better products available, or better systems available that might be in conflict with our standards, to please communicate with us. One of the very good things about the Safety Act in the United States is that we can respond instantly to changing needs. I am looking at Don Randall, representing members of the Congress here, any time our Congress initiates these things as law, it is difficult to make quick changes, but when administrative discretion is given to the Secretary of Transportation, we can make rapid adjustments. I can assure you that any time the data are persuasive, we would be willing to make these adjustments. So, I don't want to cause you to follow our Program Plan blindly. We encourage your in-puts and, in particular, we would wish that other governments and auto manufacturers in other countries would indicate where their planning might be in disharmony or out of synchronization with the Program Plan so that we may consider ways that we could improve the Program Plan.

Mr Carter I think that most of the industry would realize that the Program Plan as we published it is considered to be a planning document. We constantly have questions from the industry as to what are you thinking about next year? What are you thinking about five years from now? Well, obviously, the further you go out in time, the more flexible or the less certain we would be of the dates in that Program Plan. It is intended to provide you with some insight into our current thinking and the way our programs are being directed and to provide you with an overall plan from which our research program develops.

Mr. Toms: The dias recognizes Mr. Pocci.

Mr. Pocci: I apologize but I must once more speak to point three. I was not able to ask for the floor before. Mr. Chairman, you have spoken of international regulations and the possible influence that the ISO standards could have on national enactments. You know that I have been asked to represent this organization here in the framework of this conference and, therefore, I would like to be allowed to raise and quite officially raise a question with regard to the Committee 29 ACE one and further annotated and commented by the European committee when it had examined its work in program. The Economic Committee for Europe has recognized that the international initiative that has engendered the new technologies, advanced and sophisticated technologies, that could give safety characteristics of an improved sort to vehicles up to now unknown or unforeseen. One recognizes — one may believe that within a term that is not too far in the future, one will have interesting results of both human and financial resources from certain industries and certain governments. We did not speak here of the organization itself but it is already implied and we speak here that these new improvements will certainly benefit all nations and all industries in all countries, even those that have not participated. Some have not participated because of economic reasons in the scientific research, for such improvements must know neither language, political, social nor economic barriers.

Certainly, this is a difficult task, but I believe that the good and high intentions of the Economic Committee for Europe certainly should entrust this high task to the present conference. Having said this, I would also interject some other words which seem to be somewhat directed against the international corporation but which are very close to what you, yourself, Mr. Chairman, have said. Sometimes, one cannot wait until international regulations have already been enacted to enact national regulations. This is regrettable but at least we achieve certain results. We get certain results. But, at least, it also pushes the interested countries to find solutions. One, sometimes, is too cautious and one is afraid and one finds an excuse in international corporation not to enact national regulations. Furthermore, and while I'm fully in agreement, while such enactments are being applied on the national level, one can find better applications on the international level. What one can recommend, therefore, to the governments, those very governments that for political reasons, sometimes, are forced to enact national regulations, that certain juridical norms are such that one may then rapidly change these in view of new information. I believe that I should point out that this is a draft resolution of the European committee.

Thank you, Mr. Chairman.

Mr. Toms: Thank you, Mr. Pocci and I certainly agree and thank you for those remarks. If there are no other questions on items one, two, three and four, we will address ourselves further to number five.

The Chair recognizes microphone number eight. Professor Fiala from Volkswagen. Are you going to speak English or German?

Professor Fiala: I'll try English. Thank you. I am coming back to the question of the Program Plan. What we would like to know is what is the probability that this notice will become a standard, even in percent. So, we have an idea, for example, that this new vision angles — is very far away and the probability that a standard will follow the notice is — I don't know say 15 percent. There are some other things in the Program Plan, I feel have a probability of 98 percent. So, I think it would be a good thing, if you could state in the Program Plan what the probability is of this becoming a standard. You could give us the probability for every specific point. This would help us to know how sure you are that this specific point is very important or not. Thank you.

Mr. Toms: Professor Fiala raises an excellent point in a very valid criticism of the Program Plan. In way of an explanation, I guess in the early days of rulemaking, we often went out with an ANPRM and solicited information from the automobile industry and got very little back. So, as a result, we probably fell into a circumstance where the Program Plan did not indicate our interest in this proposal in terms of a future rule. In other words, we did not say we are dedicated to this proposition and come heck or high water so many years from now it will become a rule, versus this is a rule that we really do not think has very much merit but we think it important to put it before the industry and the public to find out if there is something that we overlooked. We did not make those differences and I think that is bad that we did not or that we do not.

Whether we can, indeed, come up with a percentage formula, such as you suggest, I don't know. I, personally, like that approach and think it would be very helpful to you and would help place our efforts in better perspective. But, I would like to defer to my colleague who toils in the vineyards on this problem all the time and get his reaction; and this will be unrehearsed. He and I have not discussed this percentage proposition.

Mr. Carter, NHTSA: Obviously, it would be quite nice if we could attach some percentage or some probability figure to a notice becoming a rule. I would like to expand a little bit on what Doug said.

In the past we have gone out many times with a so-called advance notice and more often than not we got very little response from the industry. Not only that, when we followed that with a notice, many times we got little response from the industry. So we would go ahead and establish an effective date for the rule and then the industry would sort of take the position well, it looks like it's for real; we better check into it. In the process of checking into it, they uncover problems which we all were unaware of until this particular bit of work had been done. Now, to try and avoid that, we are making a very conscious effort of having much more dialogue with the industry prior to the issuance of a notice of proposed rulemaking. We are trying to learn as much as you know about this or what you think about it prior to the issuance of the notice. We are making some progress along these lines. But, again, the industry generally does not respond until sometime after the notice is issued. While we might say, well, this has a 90 percent probability of becoming a rule, it could very well be that we overlooked something that the industry overlooked as well and then we would have to delay or change the requirements as a result of work that was either done or reported after the issuance of the notice.

Mr. Toms: We would be very willing, very pleased, to work hard at the possibility of some kind of a percentage or an indication and will assure you that we will address ourselves to that proposal and attempt to make some public statement on it in the future as to what the merits and demerits of such a plan might be.

In the interim, Professor Fiala, we are always pleased to meet with members of the industry, either individually or in groups, and try to the best of our ability to answer questions of that type.

Professor Fiala: Another question concerning question number one — the cost-benefit. I think it is really very difficult to express the value of a himan life in dollars. But, I think this is not the most important thing because we are not interested so much in the absolute value of cost-benefit but in the relative value of cost-benefit ratio of different safety standards. The one thing we would like to do is to find the right order and do the more important things before we do the not so important things. So, I think you should go ahead and say that these are only relative figures.

Mr. Toms: I agree one hundred percent. I think that we are getting closer to releasing our figures even if you do disagree with the value in terms of dollars. This does give you the chance to look at the priority with a relationship from one to another.

Professor Fiala: If you present these figures, we can discuss with you and there also the question of the precise figures of the costs will come up. Also, I think, this figure must not be very precise because I have the feeling that the cost-benefit ratio of different things is within one of a hundred and we must not discuss ten or twenty percent.

Mr. Toms: One of the reasons that we have been reluctant — some of the early discussions were so emotional and the cautions that you have just mentioned, that they cannot be very exact, were not respected in our early discussions and people nit-picked over very small amounts and caused us to back away. It is my hope that perhaps we can overcome those problems and we can come out shortly with these values.

Mr. Carter: I might expand just a little bit there, Doug. We hope to have the next issue of the Program Plan out about this fall or early winter. There will be some additions to the plan. One section will be an appendix which will give you in detail our method of conducting benefit-cost studies. We will follow that up with the detail study on a few of our rules. We will then ask you for a criticism of our technique and how it can be improved.

Mr. Toms: Are there other questions about our answers? If not, we will attempt to address ourselves to item five which dealt with lead time and our answer is basically yes, but I said that we cannot always wait for a five to a seven year cycle.

It is observed in the government that our domestic manufacturers are generally extending the time period between total model changes and perhaps some of our overseas companies might be shortening the time periods between some of their model changes. But, nevertheless, I think that it would be our opinion that we could not look toward five to seven year intervals and we would not wait that long for implementation of most rules. Now, I will concede, that if we were to rulemake on really substantive issues like chassis or body, that we may give a longer lead time than on something that wasn't quite as difficult to modify. I might relate to a knob on the instrument panel or something that might relate to tires, perhaps bulbs or lights, things of this order.

Any questions on the answer to question five?

The Chair recognizes Monsieur Clavel on microphone number one.

Monsieur Clavel: Mr. Chairman, Mr. Carter has just announced to us a new addition of the Program Plan for the autumn or the winter of this year. In connection with question five, to which you have so ably replied, I would like to raise the following question. In this new issue of the Program Plan, we should like to see, we the industry, some indications regarding the technological orientation of the contents of each of the standards that you envisage. To further elaborate on the question of lead time, what do you think of the method that may consist of indicating in advance in this Program Plan, in this new issue, not an application date of the standards, but a fixed delay that may be expressed either in months or in years, counted from the time when the requirements have truly been refined and determined?

Mr Edwards: If I understood the question basically, it was one of instead of putting the effective date for the standard, that you would want I guess you would say, technical justification for the standard and have the date being sometime after that was developed. Was that basically your question?

Monsieur Clavel: Not quite, Mr Chairman. Of course we would like to see an orientation of the technological contents of this plan, but we fully realize that you cannot give us in advance in this Program Plan a full and precise text of the envisaged standard. If one were to know it in advance, then you could enact and publish it immediately. This wasn't the question. My question deals with the manner in which you would determine the lead time which would be granted to us. Presently, the Program Plan indicates for a certain date each of the standards. For instance, October 1975 as a deadline but we do not know at which moment the technological requirements will be actually determined. That is why I asked what would you think of the method that would consist of indicating in the Program Plan not a deadline date but instead a delay which would be indicated in either months or years which would be counted from that moment when the technological requirements are truly defined.

Mr Carter: I think the answer to that would relate back to some of Doug's earlier comments. In developing any plan, we believe you have to exercise some judgment factor as to when technology will be developed and will be available. This we have attempted to do in the plan. We think that this is mandatory; otherwise we would experience what we would consider to be undue delays in the implementation of the standard. Now, this does not mean of course, that should our judgment be wrong and the technology not develop as we though it would, that the standard would not be delayed. In other words, we are exercising a judgment factor as to when something can be developed or when the technology will be available. If we are wrong we would extend the effective date of the standard. That again, is one of the purposes of the Program Plan and updating it from time to time as we plan to do this fall or early winter.

Mr Toms: I think that you point to what will probably be an on-going problem. It will always be in the financial best interests of an automobile producer to delay major modifications as long as possible; and we recognize this. We have to weigh these problems that you have financially against the public interest in terms of more efficient transportation and lives saved.

I think that you are justified in asking that we do a better job in estimating what the lead times should be and what the priorities of various rules might be within a given time period and perhaps try to relate this better to the state of the technology and do a better job of defining what might be involved in such a rule and the incumbent changes and the times that we project. I think that we can say that we will get better at doing that and we would solicit additional questions and comments from you and I can assure you that we appreciate the thoughtfulness of some of these concerns. As you communicate with us we will do a better job of meeting your needs.

If there not be another question on item five, I will talk about item six.

This is perhaps the broadest question of the six that have been posed. In the Department of Transportation, the Federal Highway Administration has the jurisdiction over our roadway system. For those of you who are close to our program, you are aware that just recently three and one-half of our state and community standards were transferred to the Federal Highway Administration. So the National Highway Traffic Safety Administration has very little jurisdiction over the roadway, for that reason, I would prefer not to trespass on my esteemed fellow administrator's ground.

Let us say that we do communicate regularly and in great depth with the Federal Highway Administration. The Highway Administration and other modal units in the Department of Transportation are clearly aware of the great need to improve our highways to make them safer.

We do have the basic rulemaking authority for dealing with the driver and the passengers in an automobile. I have said many times that we spend a great deal more money working on the driver than we spend on the car. I regret very much that I must often take what appears to be a negative position on our programs dealing with the driver. I'll take just a moment to explain why.

There are approximately one hundred fifty to one hundred seventy million people that regularly ride in motor cars in the United States. There are one hundred ten million licensed drivers. I am very reluctant to attempt to spread encouragement among the American public and State and City officials that we can swiftly and efficiently rulemake programs or develop programs that will modify the behavior of these drivers and passengers.

All the scientists that I know and my own personal background in why people behave the way they do behind the wheel, indicates to me that changes in this category come very slowly. For example, we are presently assembling up to sixty professionals on a regular basis to formulate a master driver license program for the United States. I get very enthused about the ideas that they project and the proposals that they make. I can wax for hours on the merits and the values of some of these proposals and then I have to become sober and remember what kind of money it takes to drastically change driver licensing for one hundred ten million people. How much money and time it takes to instate new educational programs for one hundred ten million people. How difficult and cumbersome it is to get state legislatures, county commissions and city councils to change their rules and their ordinances to effectively deal with people over whom they have jurisdiction.

These things take a long, long time, and I appreciate that it is the driver who guides the car that has the crash. If you could get him to avoid crashes, there are enormous savings. I have dedicated my professional life to dealing with the driver. It has only been in recent years that I have become heavily involved with the automobile. I would like very much to find a way that we could work wonders with the driver.

So, I only state that sometimes I must sound negative on these things because they are so immense and they are so difficult, but this is not to say that we aren't putting massive resources into that program and that we haven't high goals that we will try to achieve. I could show you films and talk to you about driver licensing, traffic law enforcement, alcohol counter-measures, uniform codes and laws, judicial processes, driver education, for many weeks on end non-stop, all of which are crash avoidance programs that deal with the driver. It would be my hope that your countries would be working on these programs also and that we could exchange ideas and, indeed, the CCMS, NATO programs are heavily involved in these programs.

Dr. Montabone, Fiat: I am leaving Washington convinced that if we don't find a solution to the cost problems, the present specifications of the car, unless they are slightly modified, cannot be applied to any type of car, either weight specification or size specification. But, I am also convinced as I leave, that as far as the ESV vehicles are concerned, there is a big vacuum. Something missing. In other words, the specifications for the ESV does not take into account the fact that cars not only run against walls but they also run against each other. I am also convinced, gentlemen, that it is quite difficult to take into account all of these factors between now and September. In other words, when September comes around, are we going to have a specification which is valid for the whole world?

If my president asked me to put forward a proposal by that date, I would refuse to do it, unless, and then we should state so clearly, unless we are going to think about making a standard car for the U.S. and a standard single car for Europe.

Mr. Edwards: I would reply to that to this extent. I would remind the delegates and Dr. Montabone, that from the first meeting that we had in Paris, we recognized the importance and the significance of the car-to-car collision problem. We do not pretend that we will have the ultimate solution by the end of September, but we think that we will take a significant step forward in the optimization of our specifications based upon the experience that we together have achieved over the last two-year period.

I would hope that those specifications would not be interpreted as the final solution; but by the same token, if we don't take this step, if we don't progressively improve the product, I believe we are placed in the posture of studying the problem perhaps to a point where the problem simply does not get an effective solution attached to it ultimately. So our concept then is to take the next step. It is a modification, a Mark I or Mark II vehicle. Perhaps the other cars that are being developed will take advantage of this work, your work, and input to us as much as is possible. But, as I recall my own words in Paris, the process is iterative and it must go on, least it stop altogether. So I think that is the impetus that is driving us in this case.

RULE-MAKING AND THE EXPERIMENTAL SAFETY VEHICLE PROGRAM

SECTION 3 PART 3

STATEMENT

MR. N. GEROSA, *Assistant Secretary,*
Road Safety Vehicles Division
Department of Environment

The motor vehicle has been the subject of rule-making, or regulation as we generally call it in the United Kingdom since the end of the last century. Until the last few years regulations relating to the construction of vehicles have consolidated existing good practice rather than acted as spurs to new advances. Lately, however, the tendency has developed to use vehicle regulation in two new ways: to set standards requiring features or performances which are known to be technically achievable, but which have not yet come into general application, and to act as a means of international standardization of vehicle construction requirements. Today I wish to discuss briefly the way in which vehicle regulations in the United Kingdom are likely to be affected by the Experimental Safety Vehicle programs about which we have been hearing during the course of this Conference.

One of the basic features of the development in the United Kingdom of the use of regulations to attain new levels of vehicle safety is the principle of ascertaining the technical feasibility of a standard before embodying it in a regulation. To set a standard which cannot in the current state-of-the-art be satisfactorily complied with is to run the risk of having to concede a subsequent extension of lead times, or modification of the standard, with consequent loss of credibility in the legislative system.

The present ESV project, with its associated programs in the participating countries representing all the major vehicle manufacturing nations, will result in a wealth of new information on what is technically feasible. Whether the programs consist of the development of complete safety vehicles to meet a comprehensive set of specifications or of systems and features incorporated in current production vehicles, whether they produce developments and improvements of existing safety devices or fundamentally new ideas, they will all add, and add very significantly, to our knowledge of what levels of safety performance it is possible to achieve, and by what means. This is of fundamental relevance to the future of vehicle regulation.

Another point to which we attach importance is that regulations should not be drafted so as to inhibit further development and innovation by industry. For this reason we are looking increasingly towards performance-based standards, which in effect tell manufacturers how the vehicle should behave or how its occupants should fare in a prescribed set of circumstances, rather than what specific features must be incorporated to give the desired result. The information flowing from the ESV programs will also be very relevant to this approach, and we shall find ourselves in a much better position to prepare new standards based on knowledge of what is technically feasible and expressed to a large extent in performance-based terms.

That is of course not the whole story. It is not all that is needed to justify the imposition of a new set of regulatory requirements. Modern living is increasingly subject to restrictions of one kind and another and it is always necessary to consider very carefully

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the justification for proposing to add yet more to the corpus of legislative conditions by which we are bound.

It is perhaps not uncommon to envisage vehicle regulations as a process by which unwilling manufacturers are compelled to spend money to insure that their products afford consumers the degree of safety and protection which society considers its due. But that is not a true picture. Manufacturers will provide the degree of safety that the law demands granted that it is feasible. They would and indeed do provide a considerable degree of safety without any legal compulsion at all. But they do not pay for it. It is the motorist who pays. And before multiplying regulatory requirements it is incumbent on administrations to consider very carefully whether the burden they would place on the motorist, as well as on the manufacturer, is justified by commensurate benefits.

Vehicle regulation is only one prong of the attack on the problem of road deaths and injuries. There is the equally important question of safety in road design, lay-out and maintenance and in traffic regulation and control systems, and there is the fundamental problem, overshadowing all else, of driver behavior. Vehicle regulation manifestly is not capable on its own of providing the complete answer.

The motor vehicle is a boon as well as a bane. We must beware of adding so much to it's cost — and here we need to take a sideways look at the increasingly strict environmental requirements on pollution and noise also — that it is put out of the reach of many of the people to whom it has meant much widening of their horizons.

This is not to deny the prospect of significant development in the vehicle regulation field. But it does mean that a very close study is needed of the benefits to be expected from a potential new requirement. It may superficially seem callous to attempt to apply the processes of cost-benefit analysis to measures affecting human life and health. And it is certainly fraught with difficulties. But the attempt must be made, both in order to establish the relative merits of a number of possible safety measures, and their effects on each other's effectiveness, and also to assist in determining (it is by no means the only element in the decision) the point beyond which compulsion no longer becomes acceptable. The accident and injury-saving potential of any measure under consideration, its probable cost and the likely reliability, durability and serviceability of the means of complying with it, must all be carefully examined.

Of course a number of assumptions have to be made, and it is an important function of a vehicle regulation authority to follow up by detailed accident analysis the effects in practice of a new measure to see how far they bear out the forecasts on which the decision to impose it was taken, and whether it needs to be extended or modified or even withdrawn. There is a need for stability because of the long-term time-scale of vehicle design changes, but this must not rule out a willingness to modify the system if evidence of need is produced.

It may at this point be worth mentioning again one assumption of a rather different order that is being made in the development of British safety standards. That is the assumption that the occupants of vehicles equipped with safety belts — all our new cars have had to be for several years now — will in fact wear them. We know of course that many do not. We have used massive advertising techniques and have succeeded, temporarily at least, in doubling the rate of wearing, but even so to only a little over 30%. The question of compulsory wearing is still wide open and remains to be decided by my government. So does the possibility of requiring features that make it difficult to avoid wearing the belt. But such devices are not absolutely foolproof — a word most advisedly used in this context — and we have concluded that to impose on everyone who buys a new car the cost of assuring an equal degree of protection to those who wear the belts that are provided and to those who don't would be unjustified. It is in this sense, therefore, that while we certainly intend that our standards should afford some protection to unrestrained occupants, they will be based primarily on the assumption that the belts that have to be fitted are in fact worn.

I turn now to the aspect of international standardization. This is a subject that is absorbing an increasing amount of attention and effort currently in Europe. A high proportion of most manufacturers' production is exported and correspondingly a significant part of every country's demand for motor vehicles is imported. Divergences in national regulatory requirements are a serious obstacle to this very important element in international trade and the impetus to standardization is strong. This is a matter of growing significance to Britain as a prospective member of the European Economic Community, which is developing a system of harmonized vehicle safety standards, observance of which guarantees acceptance of a vehicle throughout all the member States.

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It might be feared that this would be a development that ran counter to the interests of vehicle safety; that the tendency would be to settle on the lowest common factor of national safety requirements as the basis on which international trade ought to proceed, and that production for manufacturers' home markets would necessarily follow suit. But that is not in fact the case. The officials who get together in international efforts to harmonize vehicle standards and the Ministries from which they come, are those who also have responsibility for the promotion of vehicle safety. Their efforts have resulted and will continue to result in standards that pay full regard to safety needs. Differences of view will of course arise from time to time and progress may inevitably be somewhat slower than would be that of an individual government not bound by any considerations of international trade. But this is a dimension of the motor vehicle regulation problem that must be faced up to and cannot be wished away. When successfully met it can bring about a situation in which good safety performance can be more efficiently achieved in production vehicles through the economies of standardized production for a larger market.

Cooperation in Europe is close both in the field of regulation and of research. And there is no doubt that the cooperative ESV project will furnish the basis for a significant development in vehicle safety standards. In translating this basic material into effective regulation my Government's policy will be to urge the adoption of practical, technically achievable standards, conceived so far as possible in performance terms leaving manufacturers freedom to develop new means of satisfying them, and assuring the motorist of good value for the additional money he will have to spend, in effective and reliable improvements in safety and protection.

RESPONSE BY THE PANEL AND THE DELEGATIONS

Mr. Toms: Thank you, Mr. Gerosa, are there any further questions or comments associated with this particular session?

Monsieur Clavel, Citroen: Mr. Chairman, just a short time ago when we spoke of the optimization of the ESV program, which you have envisaged, you have been rather severe as far as I am concerned in regards to head-on collision which you said would be maintained at fifty miles per hour against fixed barrier. It would seem possible, and if not probable, that for small cars or small mini-cars in Europe, this level cannot be actually realized if one wishes to preserve an acceptable survival space, and at the same time also realize an aggressiveness index of four. These two things can quite possibly not be realizable and cannot be justified at an impact at fifty miles against a fixed barrier. In this situation, would you or could you tell us if you would be ready to requalify this problem and to also consider the impossibility of actually reconciling these two facts when you take into consideration the tests which you have seen in the past three days? This would be a qualitative reevaluation of the small vehicle such as the non-aggressiveness, the small size, the easy maneuverability, the lack of pollution or the reduced pollution by small vehicles. Could you tell us whether you could possibly alter your position as regards a mathematically very fixed threshold value when you consider these other facts that are incorporated in the category of cars?

Mr. Slechter, NHTSA: Monsieur Clavel, in my remarks today, I hope I more than hinted at the possibility of a potential decrease in a fifty mile per hour barrier crashworthiness, given that the necessary data to support a decision like that is available. We've seen in the last three days the potential feasibility of fifty mile per hour barrier crashworthiness and we've also been exposed more and more to this problem of aggressiveness. This conference brought it, I believe, to a head. My remarks indicated that I would like very much, as far as ESV is concerned and its specification discussion this summer, to speak with you and get your comments about what you feel are the practical limitations associated with that trade-off of crashworthiness at barrier speeds of fifty mile per hour and aggressiveness. There is a cost effectiveness argument, again, as we all know, I think we are all, at this table here, looking for a solution that optimizes the losses in the traffic system. Probably the most significant trade-off to be made, the most important one and the most difficult one, is crashworthiness versus aggressiveness. I think the data that was shown here yesterday by a number of representatives certainly bears out the importance of the front-end in the car's design; both in fixed object crashes and in car-to-car crashes.

Mr. Toms: I might add, Monsieur Clavel, that we are presently very carefully evaluating the use of small cars in our country as commuter cars and we certainly recognized the problems of aggressivity; the little car impacting a very large car. I think that many of us hold beliefs that if regulation in the long run becomes necessary, that we give some thought as to what the maximum size of a car could be. We do further recognize that there are limits in the quantities of fossil fuels and there are limits on this earth in the amount of ore and that we cannot continue to be a consumption society forever. Significant savings in natural resources can be gained by reducing the amount of fuel consumed and the amount of steel and other ores consumed in the production of vehicles. All of these things are being actively considered in the government today.

Mr. Boschetti: My name is Boschetti from Peugeot. In this conference, numerous documents have shown development of bumpers with energy absorption devices as a first element of contact and as an axis of the impact, particularly in the lateral impact. A bumper that is too high is an element of aggressiveness. Under these conditions, the American government and the institutions in the United States are still insisting on pendulum tests of up to twenty inches which, therefore would entail more dangerous lateral impacts? Would it not be more reasonable to have pendulum intacts with seventeen or eighteen inches of height? I believe that a draft proposition of ISO is now presently submitted and I think that this evolution could then lead to lower bumpers.

Mr. Hofferberth, NHTSA: Yes, our standards do require pendulum impacts with the center of the face at twenty inches. However, I hasten to point out that the pendulum now is a rather broad-faced configuration and it is not absolutely necessary that the bumper be at the twenty inch height to provide good pendulum contact.

Now, beyond that, in this country it is necessary to maintain a certain minimum bumper height to provide acceptable ramp clearance and acceptable operational characteristics of our cars as they currently exist. That restriction, combined with the requirement to have an adequate width to assure a good interface between cars, dictates that we test between sixteen and twenty inches. I point out that the midpoint of that range is eighteen inches, which is only about a quarter of an inch away from the ISO nominal height for bumper testing, if I am correct on that. So it is correct. We do require testing up to twenty inches.

Mr. Toms: We are very much aware of the desirability of bumpers that would contact the sill of an automobile in a lateral crash. We are painfully aware of the trade-offs that were required to get ramp angle, to deal effectively with pedestrian strikes, and the many other considerations that went into the selection of bumper height. I guess it is a fair statement that the height that was selected and the means of utilizing a pendulum was the best blend of all these compromises. We recognize that in accepting this compromise we have had to give up a bit in many categories.

SECTION 4

CONCLUDING REMARKS

Mr. Douglas W. Toms, *Administrator, National Highway Traffic Safety Administration, United States Department of Transportation*

Mr. John A. Edwards, *Associate Administrator for Research and Development Research Institute, National Highway Traffic Safety Administration, United States Department of Transportation*

CONCLUDING REMARKS
SECTION 4

MR. DOUGLAS W. TOMS, *Administrator*

National Highway Traffic Safety Administration
United States Department of Transportation

Gentlemen, it is my pleasure at this point to make a few brief remarks. First, I want to issue to you, one and all, a sincere and heartfelt apology from me personally that I could not be present at each of your sessions during this conference.

As I indicated on the first day, I was the chairman of another conference that was being held at the Sheraton Park and I was heavily involved in a third conference where I had speaking and head table duties. Also, as many of you may not be aware, the Secretary and many of the officials of the DOT, entertained and met with over sixty ministers of transport this week. All of these duties and the many agreements that had to be signed required that I be away from your meeting for sizeable blocks of time. This I regret very much and I know I speak for Secretary Volpe and Under Secretary Beggs and many of the others of us in the DOT who would very much have liked to be with you throughout the week.

I guess it is one of the sad parts of having an ESV conference during the week of Transpo that there are so many different duties and other obligations which prevented us from attending this most important conference in the manner which we would like.

So, my humble apologies, we are very sorry. We would rather have been with you but there were other duties that we did have to perform.

Secondly, during the periods that I have been here, I don't think that I have ever been more impressed with the quality of the presentations. Nor have I ever been more impressed with the fine quality of the technical information that was presented. There was a lot of depth to the presentations at this conference and I compliment you one and all for an outstanding performance.

Third, I think that there were a number of questions raised at this conference, many of which were presented in the questions here this afternoon. Clearly, there is a need for more interchange, for more dialogue, for more communication between the governments and between individual governments and the respective auto producers. I think that we must have some kind of an international conference where we can move toward more uniformity of auto regulations on a world-wide basis.

I think that we badly need some kind of a device or a mechanism where we in the United States can spend more time dealing directly with auto producers in other nations. We would solicit, again, your suggestions as to how we could best do this. Nothing would please me more than to spend a week or more on a regular basis at each of your factories. I would find this personally enjoyable but our Congress and my immediate superiors in the DOT, I am sure, would not permit me that much time. However, this does not mean that there are not ways that we can communicate better or that our colleagues in the government could spend more time at your factories or that we could get together more consistently with other governments to try to solve some of these problems.

I think that this conference here this week, the high level of attendance, all of you here patiently paying attention, hour in and hour out, the representation of many presidents, vice presidents, chief engineers, indicates that truly the world is concerned about automotive safety. I again compliment you for the dedication, the money, the resources, that you have put into the problems that are facing us in automobile safety. I think that you all are to be congratulated for your efforts. I am very gratified by the amount of information that is available to us today, world-wide, in the field of automotive safety that was not present two years ago. So, indeed, a great deal of progress has been made.

I am enormously gratified. I am so very pleased that you all did come and that you are here and that the evidence of your efforts, since the last conference, indicates a superlative effort. My hearty congratulations. I look forward to the next ESV Conference, and dedicate all of us in the United States government to do everything that we can to make your burden easier and yet to help us save more lives on the highway.

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MR. JOHN A. EDWARDS *Chairman*

Associate Administrator for Research and Development
National Highway Traffic Safety Administration
United States Department of Transportation

Certainly the level of technical exactness being reported has steadily increased over the course of the three conferences that many of us have had the opportunity to attend. Witness how the conference reports, themselves, are getting bigger and bigger, and of course more important, how they are being used by our engineers and technologists. Certainly, international cooperation has clearly been aided and abetted by these conferences.

It has been a very personal and very meaningful professional experience for me to have served as your conference chairman for these three international conferences. I thank you very much and I declare this ESV meeting closed.

UNITED STATES
INTERNATIONAL
TRANSPORTATION
EXPOSITION

transpo 72

DULLES
INTERNATIONAL
AIRPORT,
WASHINGTON, D.C.
MAY 27-JUNE 4

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special section

EXPERIMENTAL SAFETY VEHICLES AT TRANSPO '72

The United States International Transportation Exposition, "TRANSPO '72," was the largest industrial exposition of its kind ever held, and the first entire exposition sponsored by the United States Government. Under an Executive Order signed by President Nixon on June 29, 1970, the Secretary of Transportation, John A. Volpe, was in charge of organizing and directing Transpo '72 which dealt with all modes of transportation. A total of 173,000 sq. ft. of indoor and 586,000 sq. ft. of outdoor space was used by over 600 exhibitors from 12 countries in displaying transportation products and services of the future.

In conjunction with the exhibits a total of 21 technical conferences and meetings were conducted with an aggregate registration of approximately 4,000. The Third International Technical Conference on Experimental Safety Vehicles was one of the conferences held during Transpo '72.

A major attraction at Transpo '72 was a consolidated International Experimental Safety Vehicle Exhibit at which twelve different experimental safety vehicles (ESV's) produced by domestic and foreign firms were on display. The exhibit provided the approximately 1 million visitors from all over the world a striking glimpse into the future of safer driving and vehicle safety.

The ESV prototypes, now and for some time to come, will be "idea" cars, although it is expected that many of their safety innovations will soon find their way into the production line.

The search for a "safe" automobile was spearheaded by the U.S. which seeks development of a 4,000 pound class "family sedan" type of ESV. Working at the international level, the U.S. is emphasizing three major goals:

- Development of new vehicle safety technology.
- Full cooperation among all participants in sharing new technology as it develops.
- Incorporation of prototype safety feature standards for mass production vehicles that reflect worldwide needs and research experience.

The development of experimental safety vehicles is designed to produce a "quantum jump" over the customary year by year, step-by-step evolution in the auto industry.

The special display of experimental safety vehicles was sponsored by the U.S. Department of Transportation's National Highway Traffic Safety Administration. Shown below is the exhibit dome, which was 120 feet in diameter and 49 feet high with 10,000 square feet of floor space. In addition to the ESV's the dome contained an NHTSA exhibit showing visitors how they could help from becoming a crash statistic. It featured information on drunk driving counter-measures, vehicle safety standards and driver performance being encouraged by the 50 U.S. States under the Highway Safety Act of 1966.

Representing the Federal Republic of Germany were the ESV's of Mercedes-Benz and Volkswagen. The United Kingdom displayed its MG and Triumph, with components of ESV equipment developed by British industry and installed in the two cars. Italy was represented by the Fiat ESV, and Sweden by the Volvo Experimental Safety Car. Toyota and Datsun, represented Japan in that country's ESV efforts. The United States showed off its entries with the AMF, Fairchild-Hiller, Ford, and General Motors ESV's. The Japanese, British, Swedish, German, and Italian vehicles were shown in the U.S. for the first time.

Details on ESV innovations, along with photographs of each car are given on the following pages.

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AMF

The United States

AMF EXPERIMENTAL SAFETY VEHICLE

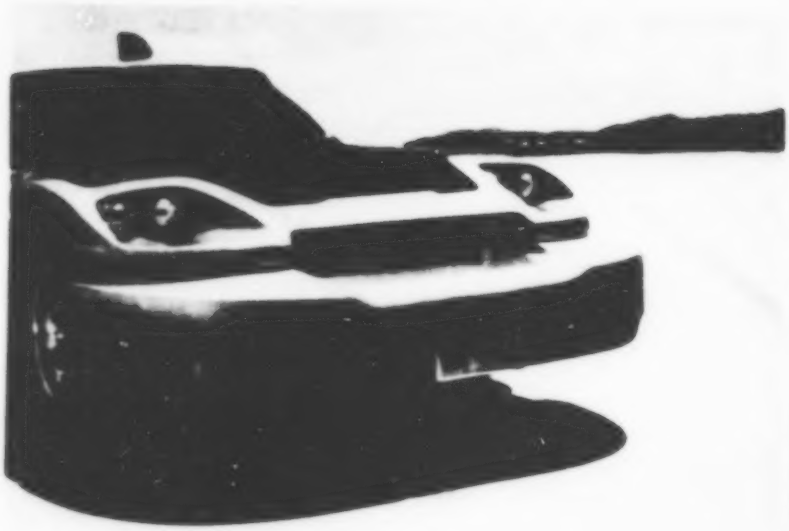
The AMF vehicle encloses passengers in a high strength steel "space frame," using hydraulic bumper systems, front and rear.

All parts of the frame are welded and consist of main frame elements running the length of the vehicle, perimeter frame elements, A, B, and C posts and pillars, roof rails and cross members, and frame cross members. Door beams are fabricated of aluminum honeycomb covered by aluminum front and rear sheets with high strength steel hinges and pin clevis assemblies. The energy absorption potential of this design stems from the stretching action of the aluminum skins, along with the crush of the honeycomb material. All exterior panels are fiberglass.

Front and rear bumpers are made of high strength, aluminum alloy forgings covered by plastic absorption material and vinyl. Designed as a velocity sensitive system, the front bumper returns to normal position after impact of 10 mph, and strokes 30 inches to absorb the impact of a high speed collision. The rear bumper strokes only 14 inches. The system is designed to protect passengers up to 50 mph.

Additional low speed passenger protection is provided by extensive use of polyurethane foam, sculpted and glued in place in the passenger compartment. The material is 2-3 inches thick on the pillars and 3-4 inches thick on the doors and other areas.

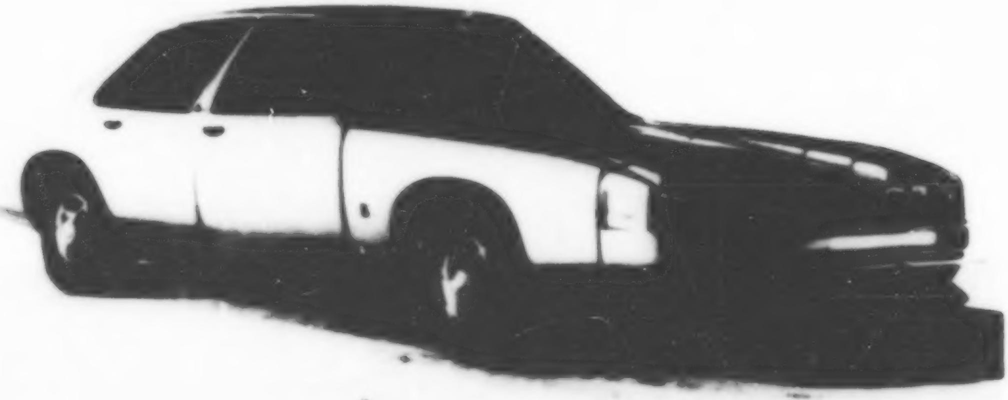
High speed passenger protection is also afforded by an air cushion system, one housed in the steering wheel hub for the driver, the other in the dashboard for the front seat passenger. Rear seat passengers are protected by air cushions deployed from the B pillar cross member.



GM

The United States

GENERAL MOTORS EXPERIMENTAL SAFETY VEHICLE



General Motors' ESV prototype uses a specially engineered bumper and energy absorbing frame to afford maximum occupant protection.

Two thirds of the impact forces are absorbed through the frame, and one third by the front sheet metal and hood, and doors. A front hydraulic bumper absorbs part of the impact, the remaining force by a collapsible truss system, and the balance through the drive train. Aluminum is used for body panels, bumper, and door beams. Vanadium alloy steel is used in the frame body side pillars. The frame design features a full box section with both cros and diagonal bracing to handle corner impacts.

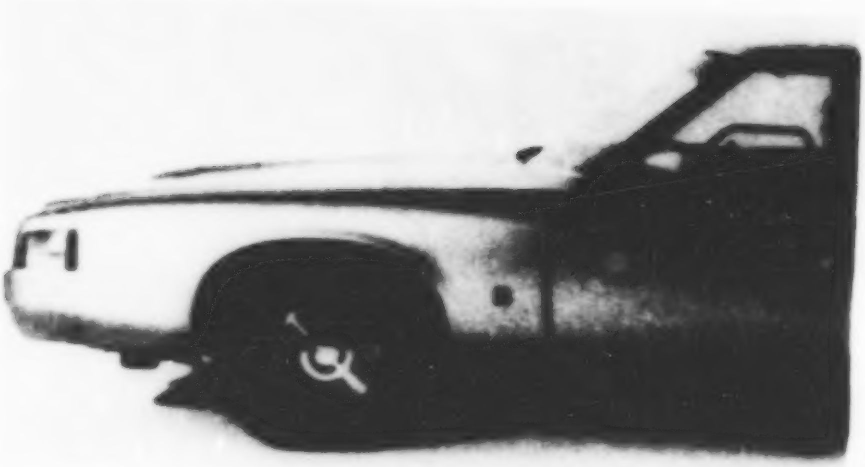
The urethane covered bumpers have a 2.5 inch stroke in a 5 mph barrier impact.

High strength roof supports in the center pillars provide rollover protection, with the forward slope of the pillars reducing the amount of unsupported roof structure over the front seat area.

Dual piston disc brakes are used for each wheel, with two separate, dual master cylinders to eliminate a single line failure. The braking system also incorporates load proportioning and wheel lock control devices at each wheel.

Front and rear suspension systems on the vehicle are of basic production configuration, modified to meet requirements for steering and handling. Coil springs and a roll stabilizer are used in the front system with coil and pneumatic springs, operating in parallel for the rear.

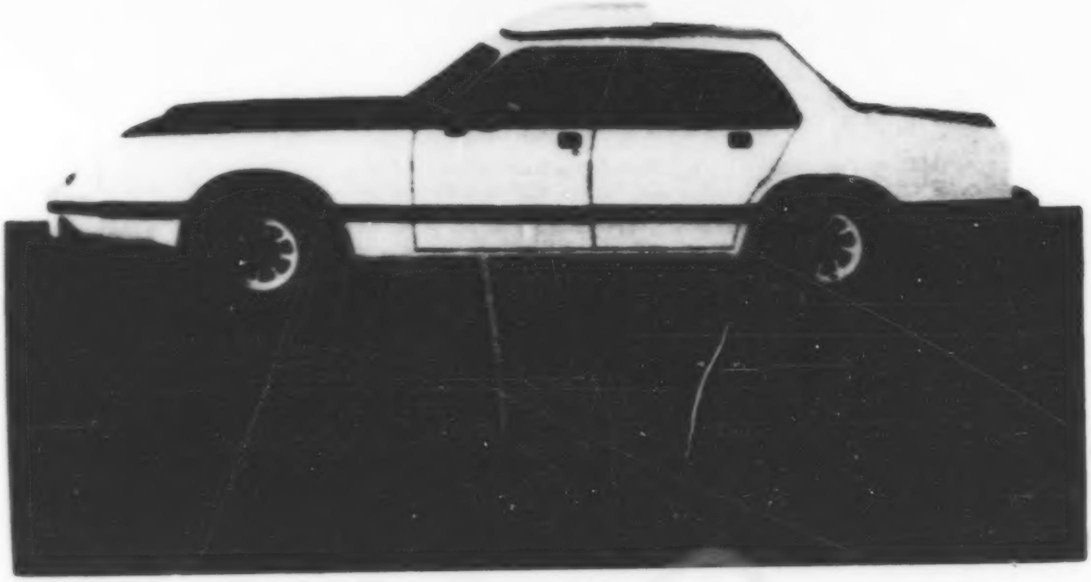
The interior contains sufficient padding to permit the "survival" of unbelted test dummies in barrier impacts of 20 mph. At the same time, the car is equipped with an air cushion system that deploys from the steering wheel for the driver, the instrument panel for front passengers, and a padded "credenza" for rear seat passengers. The air cushion systems are actuated by sensors in the front bumper.



Fairchild

The United States

FAIRCHILD EXPERIMENTAL SAFETY VEHICLE



Fairchild's safety car features special bumpers and a roll cage structure to enable it to withstand a range of crash conditions.

The front bumper automatically extends 12 inches forward at speeds above 30 mph to provide an extra cushioning stroke for high speed impacts. Retracted, the variable orifice hydraulic cylinders which actuate the bumper have a stroke range of 18 inches for low speed impact. Thus, for high speed impact the cylinders have a stroke range of 30 inches. Torsion pins, connecting the bumper with the cylinders, are used to improve performance in angular collisions. The bumper retracts when the transmission is shifted to "reverse" or "park".

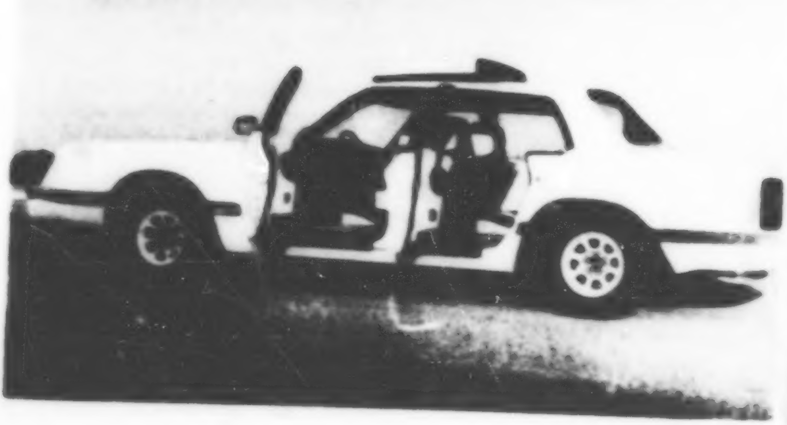
The rear bumper is connected to the frame by torsion hinges designed to yield at impacts above the "no damage" level of 10 mph. Below this speed, the force is absorbed by special energy absorbing foam material. Both bumpers are steel core, covered by plastic foam and vinyl.

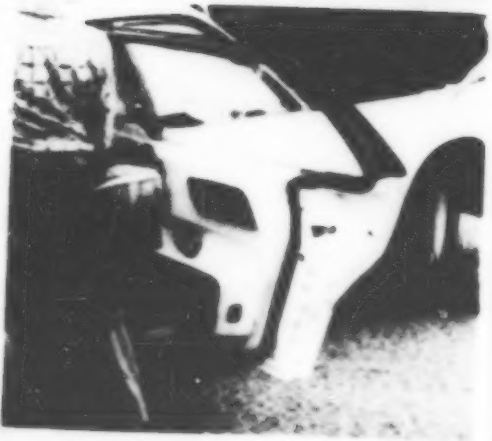
High strength steels are used in the frame and conventional sheet metal for the outside. Stainless steel and a combination of metallic honeycomb structure is used in the doors and lower sills to provide side collision protection for either car or pole type impact. Rollover protection is provided by roll bars, which are directly integrated with the B and C pillars, and a steel radiator bulkhead.

The driver and passengers are protected by air cushions and extensive use of padding and other energy absorbing materials. Air cushions deploy from a deep dish steering wheel for the driver, from the dashboard for the front seat passenger, and from a vented roof compartment for rear seat passengers.

FAIRCH

FAIRCHILD

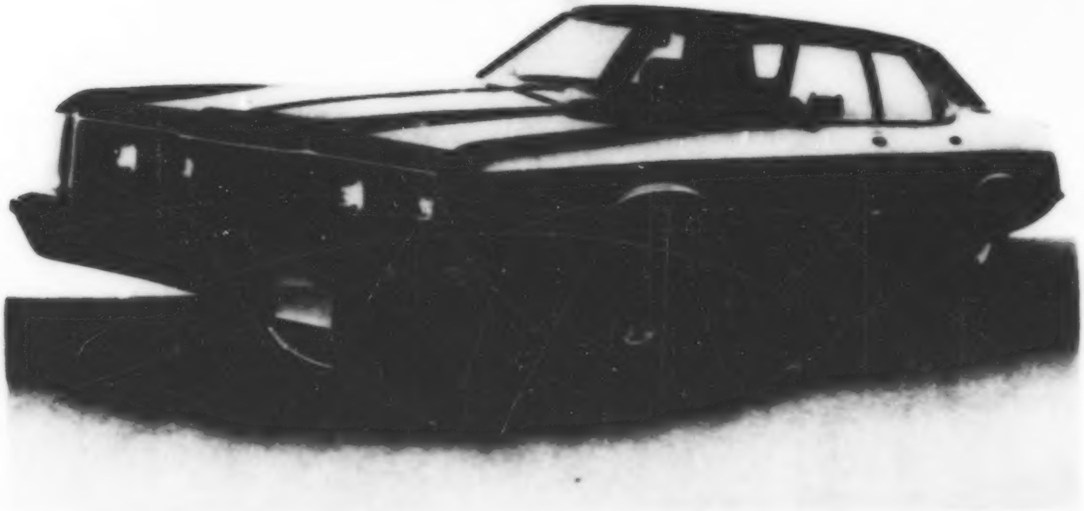




Ford

The United States

FORD EXPERIMENTAL SAFETY VEHICLE



The Ford Motor Company uses a modified standard production model which includes an energy-absorbing frame, impact-absorbing bumpers, and a reinforced body.

The frame is designed to absorb 65 percent of the energy generated in a 50 mph frontal barrier crash. It uses four convoluted steel sections to soak up energy as they compress in response to impact forces.

The body front end, incorporates a "controlled-collapse apron," which is located over the front wheels, ahead of the engine compartment. This is designed to absorb the remaining 35 percent of crash energy.

The front bumper is made of a special high-strength alloy to absorb a 50 mph pole impact. The front bumper extends further than a conventional bumper to allow room for a 9-inch stroke of the hydraulic struts which secure the bumper to the frame. Both the front and rear bumpers have a special "cosmetic" covering which, with the hydraulic struts, should enable the bumpers to meet 10 mph "no-damage" objectives.

The vehicle has reinforced side pillars, roof panels, door guard rails, and two unique beams which cross the car immediately behind the fixed front seat – one at floor level and one about half-way between the floor and the roof.

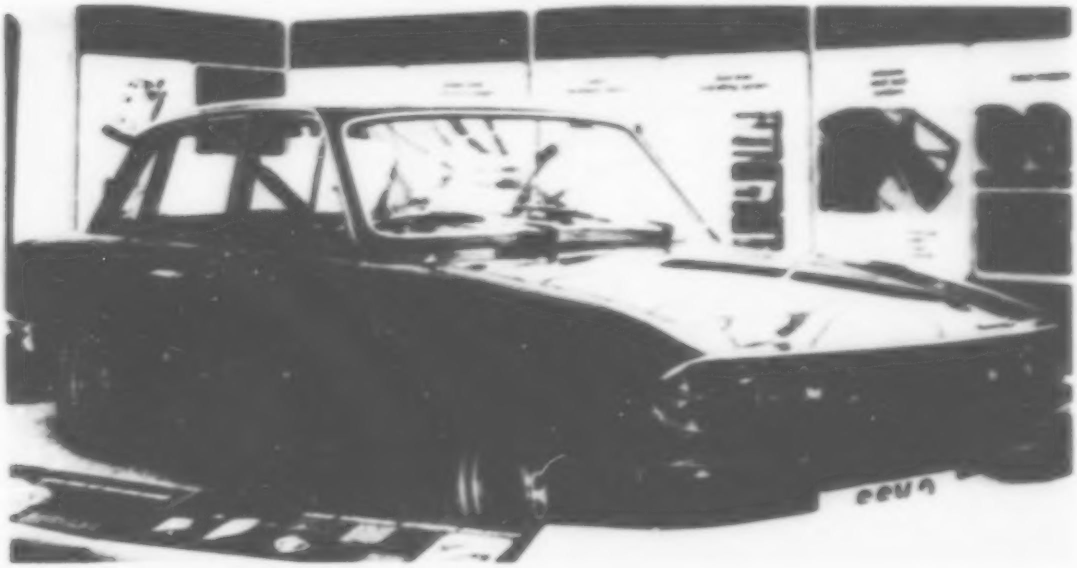
Additional passenger protection is provided by a structural tunnel, running between the two front seats. The transmission shift lever and other controls are located in a console mounted on the tunnel in order to provide space in the instrument panel for restraint devices and associated hardware.

The car is fitted with passive occupant restraints. These systems use three different air cushion designs. For the driver, there is one unit in the hub of the steering wheel and a second in the instrument cluster. These are augmented by a collapsible steering column and knee panels. For the front passenger, there is a single system. A large, common air cushion system is mounted on the back of the front seat for those riding in the rear.

Triumph

The United Kingdom

TRIUMPH EXPERIMENTAL SAFETY VEHICLE



The Triumph SSV 2 reflects safety ideas consistent with European thinking and future legislation on vehicle and passenger safety.

The Triumph uses the Girling-Lucas protection system, which eliminates wheel locking and skidding, with no loss of steering control and overall stopping distance.

Self-leveling headlights counteract misaim and increase of glare. A headlight cleaning system maintains lighting efficiency and the "Autosensa" device projects a high intensity beam to augment normal dimmed headlight beams. An automatic mirror deflects the dazzling reflections of following cars.

A vehicle monitoring system is used to display malfunctioning of the vehicle. Conditions monitored by this system include brake alert, oil pressure, bulb failure, brake pads, brake fluid, oil and windshield washer levels.

A radar system is undergoing research to maintain safe distance between vehicles on expressways.

SSI 2

V2

SSV

MG

The United Kingdom

MG EXPERIMENTAL SAFETY VEHICLE

The MGB/GT SSV I is a modified production model featuring restraint and safety protection devices and active ride control and anti-lock brakes. Side strength is increased by internal door guard rails, and by filling hollow box members with structurally rigid polyurethane foam to inhibit collapse. The bumper has a strong steel main member built up into a padded section with a stiff foam "nose" covered with a tough outer skin to distribute the load on impact. A new hydraulic anti-roll suspension provides constant ride height and eliminates roll and pitching.

A full passive restraint air bag system is actuated by a sensor on the front bulkhead, and an alcohol screening tester is used to reduce the problem of the intoxicated driver. A periscopic system uses there plane mirrors for over the-roof wide angle rear viewing.

A speed and distance warning system provides a means of maintaining adequate spacing between vehicles. Two vertical lines are projected on the windshield in the driver's line of vision. The spacing of the lines is proportional to speed and approximates the width of the car in front for safe following distance. An anti-lock system to prevent skidding is incorporated into hydraulically pumped accumulators for fail-proof brakes.

Volkswagen

Federal Republic of Germany

VOLKSWAGEN EXPERIMENTAL SAFETY VEHICLE

Volkswagen's ESVW utilizes a combination of rigid perimeter "tough shell" construction backed by crumple zones that deform and absorb crash energy at known rates.

In low speed collisions from the front or rear, telescoping hydraulic bumpers absorb impact and return to normal shape and position with no damage. At higher speeds, after the initial impact absorption takes place in the bumper cylinders, a back-up hydraulic system takes over until at high speeds the sheet metal itself becomes the energy absorbing medium. The front bumper has a total telescope stroke of eight inches, while the rear bumper has a five-inch stroke and absorbs a 5 mph impact without damage.

The ESVW does not use air bags. Instead it is equipped with a passive, pre-loaded, energy-absorbing restraint system utilizing a shoulder belt and a knee belt.

An across-the-chest belt hands loosely in front of the occupant in normal driving and there is no knee restriction. In a low-speed collision, the occupant is restrained by the loose belt and a padded knee bar. At speeds over 15 mph, as the front bumper telescopes inward at the moment of impact, a sensor located inside the bumper sets off a charge within a closed cylinder. Gas expansion activates a device which tightens the belt across the occupant's chest and deploys the lower belt that grips his knees.

Force limiters in the shoulder and knee belts are designed to "give" at a predetermined load so the wearer can "ride out" the collision inside the rigid passenger compartment. The belts avoid problems that air bags present such as potential for inadvertent firing, and no protection at speeds below their triggering level.

The front seats are unitized with the floor structure, the central "backbone", and the strong transverse bulkhead. Seat backs are designed to absorb energy in rear-end collisions.

Mercedes-Benz

Federal Republic of Germany

MERCEDES-BENZ EXPERIMENTA SAFETY VEHICLE

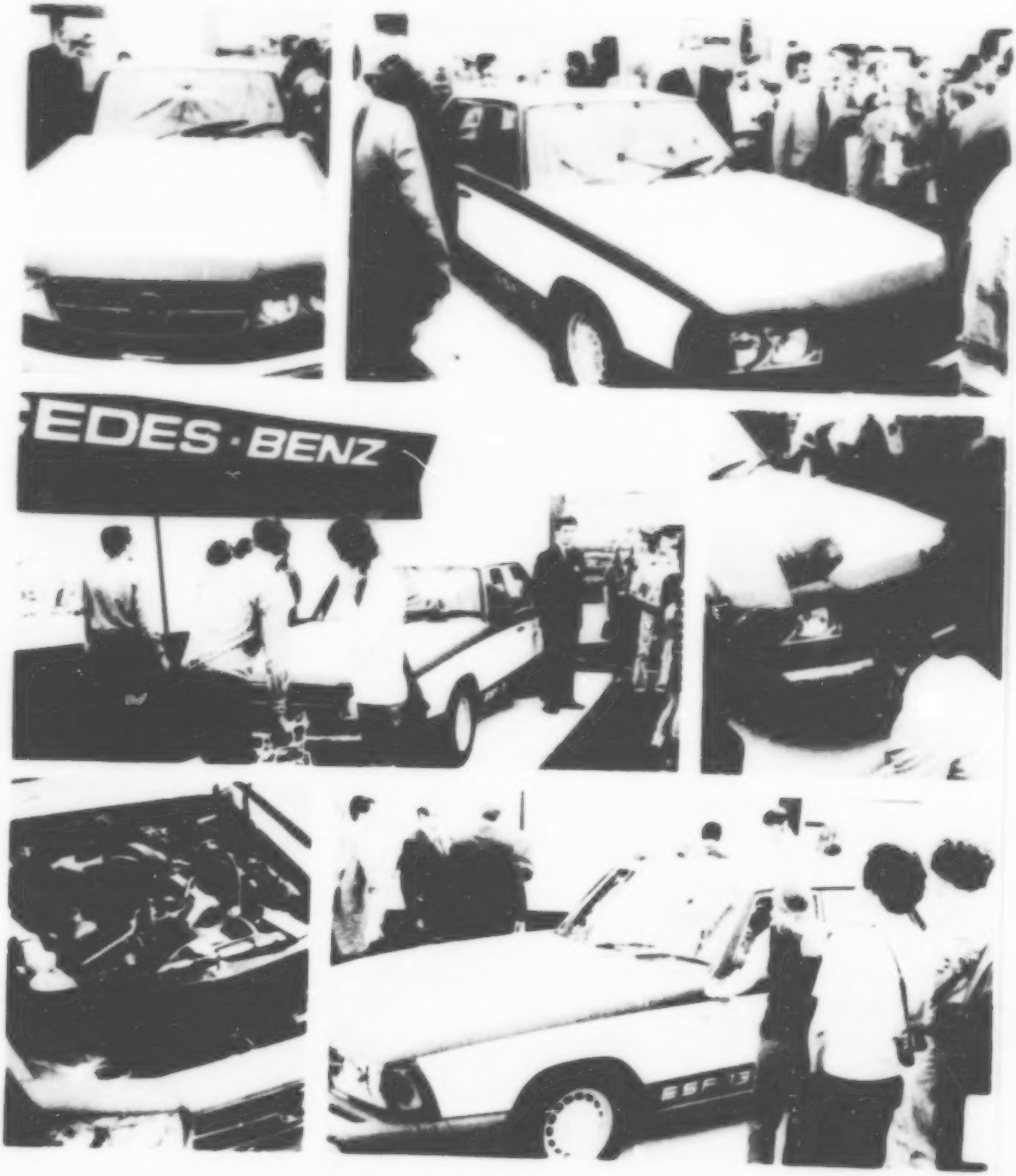
DB-ESF 13
ESF 13

The Mercedes-Benz ESV 13 has been developed from the company's basic 250 model using regenerating shock absorber bumpers and passive and active passenger restraint systems. Three-point safety belts are used for all passengers, with dual sensitive emergency locking retractors for the three rear seat passengers. Air bags are provided for all passengers.

The ESV 13 is a five-passenger sedan with a weight of approximately 4,620 pounds and a wheelbase of 112.2 inches, or the same as the standard 280 SEL Model.

The most notable feature which is not required by the ESV performance specification is the ABS system, an anti-lock braking device that enables the vehicle to be stopped in the shortest possible distance regardless of the type of road surface and regardless of whether the surface is wet or dry.

Other unusual features are a rear seat head restraining net, a wiper for the rear window, corrugated tail lights that stay bright by resisting dirt build-up, washers and wipers for headlights, and attractive styling.


EDES · BENZ
ESF 13

Volvo

Sweden

VOLVO EXPERIMENTAL SAFETY VEHICLE

The Volvo ESV uses a system of high-strength steel members to protect the car's body. A rollover bar crosses the roof and tubular steel reinforcements run along the body inside the doors. Special hooked-units lock securely onto door posts to minimize side impact effects and to reduce intrusion into the passenger compartment by another vehicle. On impact in frontal collisions the engine is forced under the car, avoiding the extreme hazard of engine block intrusion into the passenger compartment.

At speeds up to 10 mph against a fixed barrier, the protruding front bumper flexes seven inches to absorb impact and protect the car body from damage. The rear bumper flexes three-and-one-half inches against a movable barrier at the same speed.

The front seat is equipped with semi-passive safety belts which come into operation automatically when the car is started and the handbrake released. A spring-loaded steering wheel lessens the chance of driver injury by pulling away in a frontal collision. Activated on impact by a deceleration sensor, the spring pulls the steering wheel forward six inches.

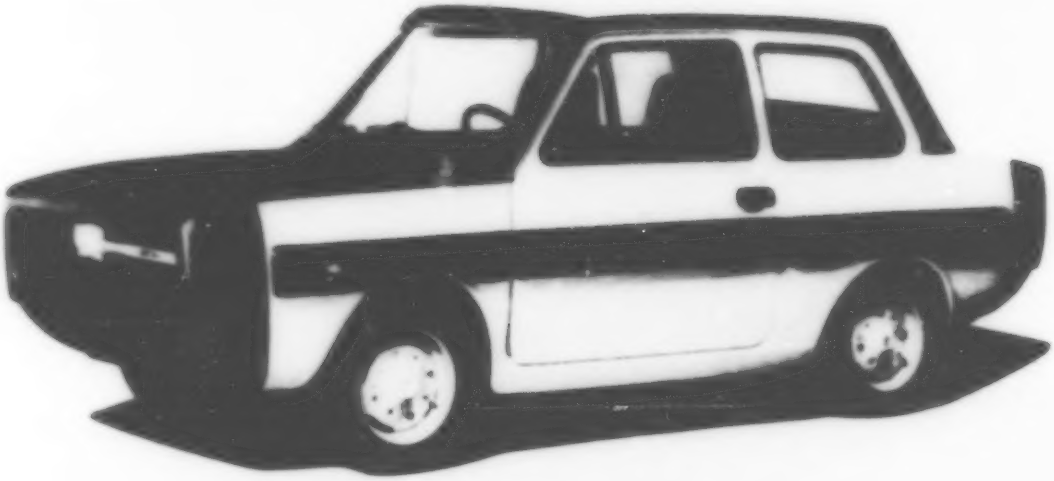
Air bags are included for all occupants, including those on the rear window shelf to protect back seat passengers in rear end collisions. Front seat head restraints are built into thickly-padded seat back rests. In a collision, they pop up automatically to provide added protection.

5.
VOLVO
VOLVO

Fiat

Italy

FIAT EXPERIMENTAL SAFETY VEHICLE



The Fiat prototype gave priority to project design and development of an experimental safety car in the lighter weight class. This was partly on account of the irreplaceable role of this type of vehicle in popular motoring, and partly because the safety standards proposed for this class are likely to weigh particularly heavily on the cost/profit ratio.

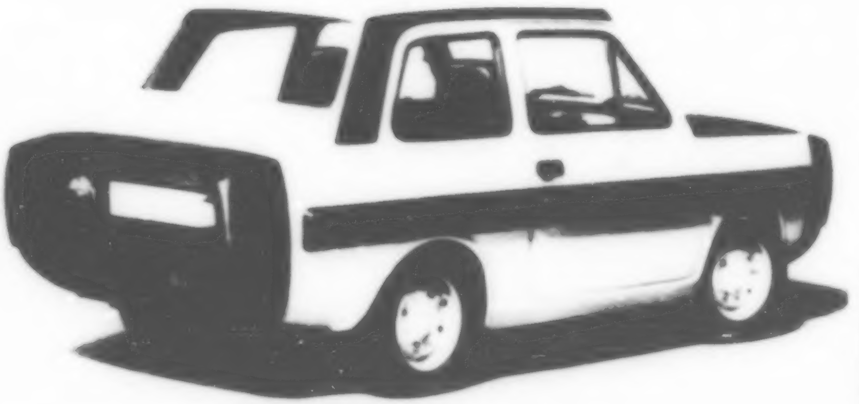
The prototype was developed after a preliminary cycle of project designs and tests aimed at improving the crashworthiness of the 500 sedan, the smallest current Fiat production car.

The car body end sections, of identical shape, consist of two easily removable deformable elements secured to the body work metal structure. These elements in addition to providing protection during front and rear collisions also reduce car aggressiveness, particularly in the event of striking a pedestrian.

The elements of the body structure reflect unique design solutions to the problem of collisions with heavier weight cars.

Fiat is testing two different self-regenerating bumper systems, one uses bladders filled with elastically compressible synthetic foam, and in the other, the outer sheath of the bumper is filled with synthetic foam endowed with particular elasticity and hysteresis characteristics.

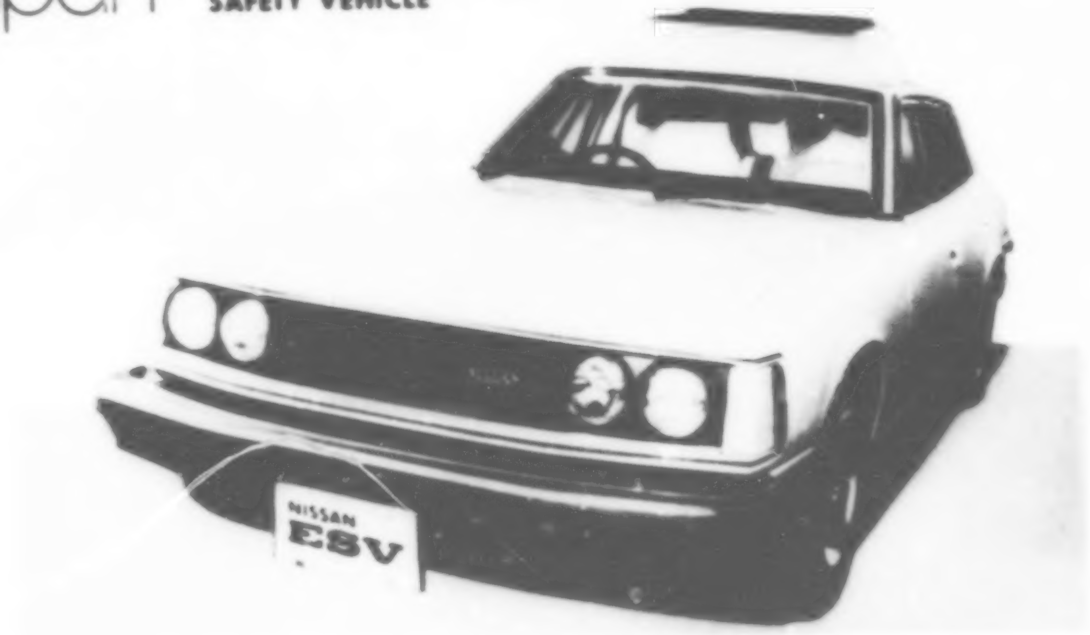
Weight increases over current production 500's is estimated at 46% with a cost increase of approximately 40%.



Datsun

Japan

DATSUN (NISSAN) EXPERIMENTAL SAFETY VEHICLE



The Nissan Motor Company's ESV is a modified production model of the Datsun 510 sedan designed to insure the occupant's safety in a 50 mph barrier crash.

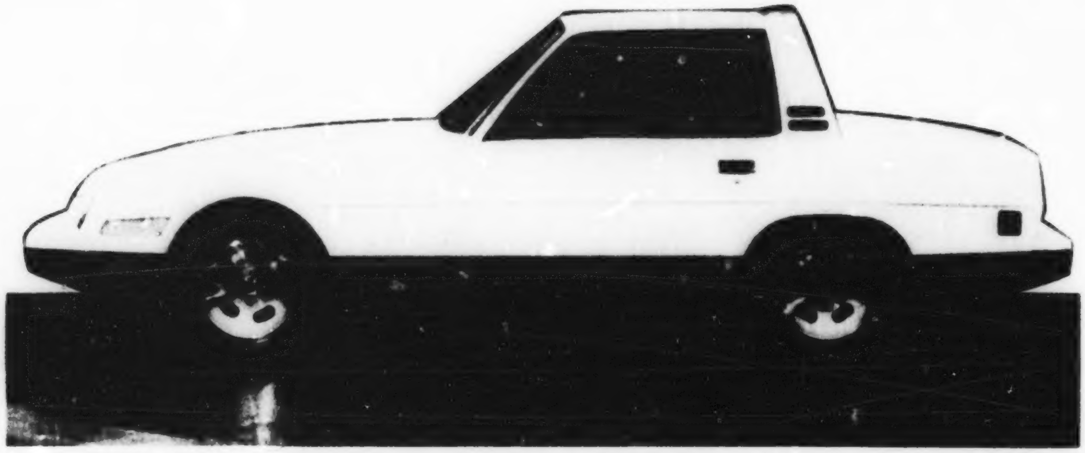
Some of the more significant safety-performance features of the Nissan ESV are a body structure with a combination of rigid passenger compartment and energy absorbing front and rear ends, explosive-type airbags (with a radar sensor now under consideration) and thick padding to protect occupants, safety bumpers to withstand damage in minor collisions up to nine mph as well as non-inflammable interior materials, a roof-top periscope providing three times as much rearward vision as the conventional mirror.

ESV

Toyota

Japan

TOYOTA EXPERIMENTAL SAFETY VEHICLE



Toyota Motor Company's experimental safety vehicle features an impact absorbing frame and fire wall, an engine that falls away from the vehicle upon impact, self-inflating protective cushions, reinforced side and roof, automatic skid control, and increased visibility for occupants.

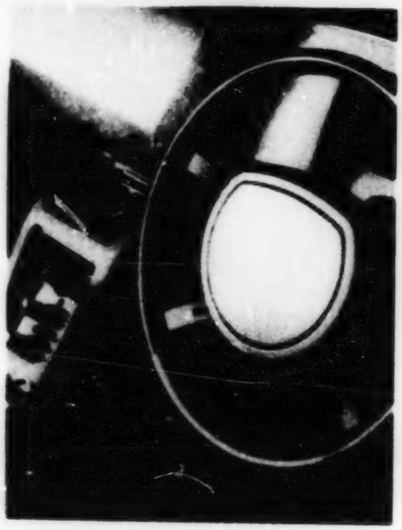
A two-seater car, it is claimed capable of protecting occupants in head-on crashes up to 50 mph and roll-over accidents up to 60 mph.

Toyoto uses a computerized gas bag system that inflates a split second before impact. Microwaves, emitted by a sensor in the front of the vehicle, are reflected off approaching objects. The reflections are received by electronic circuits, which determine the speed and distance of the object and trigger gas bag inflation before collision.

Special structures that reinforce side strength give the ESV great resistance against dangerous lateral impact from other vehicles or fixed objects. The top is also built to withstand the impact of rolling.

Toyota's ESV features impact-tolerant front and rear body construction, a bumper that keeps the car free of damage in collisions up to 9.3 mph, thick interior padding, lap and shoulder belts, and a shock-absorbing steering column.

For future models, Toyota designers are working on a special instrument that automatically checks crucial items before the car starts. To insure the car is roadworthy, a computer will check such items as brakes, oil pressure and headlights and indicate their condition by flashing either a green (o.k.), yellow (take action), or red light (immediate repair or adjustment required).



TOYOTA
EXPERIMENTAL SAFETY VEHICLE

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